Working Hours in the Democratic Economic Planning (DRAFT)

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August 29, 2025

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1 The Quest to Minimize Necessary Labor

Thesis. We can live better and work less by using democratic economic planning to allocate labor to human needs. Optimization turns public goals into concrete production plans that minimize necessary work.

Hook. Lights-out factories and robotic greenhouses exist, yet most people still work about forty hours and feel time-poor. The constraint is institutional, not technical: automation gains are privatized, not socialized as free time.

Claim. Planning makes productivity a collective time dividend. Society sets service floors and ecological ceilings; models trace hours through supply chains; optimization minimizes human hours subject to quality, safety, and sustainability.

Promise. Each sector chapter reports weekly hours per 1,000 people under low/medium/high automation, then in the last chapter we roll up to city and national totals and compare with the present work hours.

1.1 The Contradiction We Live In

Productivity rose for decades while the standard week barely moved. Core technologies—automated assembly, predictive maintenance, controlled-environment agriculture, power electronics, routing algorithms—lift output per hour but do not shorten weeks. The reason is structural: firms expand output or margins; fragmented bargaining and partial public guarantees leave individuals priced into full-time norms. Time saved by machines becomes profit, inventory, or new product lines, not less necessary labor.

Necessary labor. We define *necessary labor* as the total human hours strictly required to secure a decent living standard for all at agreed service levels and within ecological limits. It excludes superfluous production, avoidable duplication, speculative churn, and administrative overheads of market fragmentation. We separate:

- *Direct hours*: frontline provision (e.g., nurses, teachers, operators, drivers, growers).
- *Indirect hours*: upstream support embodied in inputs (e.g., fleet maintenance, manufactured supplies).

Two principles anchor the concept: (i) set sufficiency first (nutrition, shelter, care, education, mobility, water, energy, connectivity); (ii) minimize hours subject to safety, quality, reliability, and ecological ceilings.

From hours worked to hours needed. Current hours reflect legacy processes, uncoordinated chains, marketing throughput, and the costs of billing, credit, and intellectual property. Planned coordination can remove duplication, raise utilization across shared assets, standardize for repairability, and reduce required labor without lowering service.

The labor footprint. We use the *labor footprint*: the sum of direct and indirect hours embodied in a person's or community's basket at a given service level. The footprint (i) traces hours through multi-tier supply chains, (ii) makes visible imported labor, (iii) separates essential from discretionary demand, (iv) responds to technology choices (automation, standardization, preventive maintenance) and institutional choices (public provisioning, shared infrastructure). If the footprint for decent living is far below current hours, the gap is a map for shortening the week while improving quality and equity.

1.2 What Planning Changes

Planning reframes decisions around an explicit *hours budget*. Society chooses a social workweek, allocates time across essential domains, and enforces three guardrails:

- **Sufficiency thresholds**: kcal/person/day; habitable m^2; nurse–patient ratios; transit frequency; safe-water liters; reliable-energy kWh; connectivity Mbps.
- **Ecological limits**: caps on materials, land, water withdrawals, emissions, and waste; priority to durable, repairable designs.
- **Equity targets**: fair work-time distribution, training throughput, regional access parity, and inclusion of care in the time budget.

Optimization as method. Once ends are public, models minimize required labor while meeting constraints:

- **Input–output tables** map interdependencies and propagate indirect hours.
- **Technology coefficients** convert techniques into hours per unit of service (throughput, uptime, scrap, maintenance).
- **Constraints** enforce floors, reliability, safety, and ecological ceilings.
- **Objectives** first guarantee sufficiency and compliance, then minimize hours, then smooth queues and inventories.

The result is a reproducible plan whose assumptions and code are open to inspection and revision.

Examples:

- **Food**: minimize hours per nutritious kcal within soil and water limits; consolidate logistics to remove duplicate labor.
- **Housing and infrastructure**: modular retrofit and preventive maintenance to flatten labor spikes and cut lifetime hours.
- **Care sectors**: staff to sufficiency ratios; digitize paperwork before touching bedside time.
- **Utilities and mobility**: coordinate grids, depots, and timetables to raise utilization and reliability while cutting idle labor.

Across domains, standardization, shared platforms, and repairability reduce recurring hours without lowering service quality.

1.3 How We Compute It

Each sector chapter follows one pipeline:

- **Baseline and scope**: define the essential service (e.g., nutritious kcal/person/day; habitable m^2; nurse–patient ratios; vehicle-km of public mobility).
- **Service levels**: set explicit floors and quality constraints with ecological ceilings.

- **Ratios and routes**: derive staff:population ratios and process maps for low/medium/high automation.
- **Utilization and reliability**: size buffers, shifts, maintenance; impose uptime and safety requirements.
- **Coefficients**: translate techniques into throughput, scrap/rework, and preventive-maintenance loads.
- **Metric**: report weekly hours per 1,000 people.

1.4 From Hours Saved to Freedom Gained

When necessary labor falls, the freed hours are budgeted back to society by policy:

- **Shorter weeks**: staged reductions (e.g., $40 \to 34 \to 30 \to 24 \to 20$) tied to service reliability and productivity milestones.
- **Universal basic services**: public provisioning of food, housing, healthcare, education, mobility, water, energy, and connectivity so fewer hours do not mean insecurity.
- **Equity**: rotate unpleasant tasks; automate drudgery first; recognize and resource care; retrain from low-value churn into foundational sectors.

Time dividends become free time for all, not unemployment for some.

1.5 From Feasibility to Power

The models are technical; implementation is political. Without changing who decides and what production is for, saved hours are reabsorbed as private margins. A democratic planning economy—public ownership and direction of foundational systems; open planning institutions with auditable models and data; legal guarantees of service floors and a shorter week; job and training guarantees; ecological sovereignty—turns feasibility into rights. Planning allocates time; democracy claims the right to do so.

1.6 What this work claims and shows

This work demonstrates, with transparent calculations, that we can sustain a high standard of living with roughly a 10 hour workweek per person when services are organized under democratic economic planning. The chapters quantify the weekly human hours per 1,000 residents needed to meet non negotiable service floors across food, housing, care, mobility, utilities, materials, and culture. The result is a shorter week with better services, not austerity.

Examples of service floors guaranteed

- Three hot meals per day in community kitchens and restaurants, seven days a week.
- Decent housing for all, climate resilient by design, with funded maintenance.
- Universal healthcare and education, with contact time protected.
- Reliable mobility, clean water and sanitation, affordable energy, and open digital access.
- Public spaces, libraries, culture, sports, and parks available to everyone.

How we prove it

- Define floors and exclusions first; no tradeoff against quality or safety.

- Use conservative coefficients and best practice rates to compute hours per 1,000.
- Separate contact work from administrative overhead; automate only the latter.
- Aggregate stocks and flows across sectors; publish totals and sensitivity.
- Convert totals to a social workweek as a function of labor force participation.

2 Defining Decent Living

This chapter fixes common **targets** and **constraints** for all sector models. We use **global defaults**, report per-capita and **weekly hours per 1,000 people**, and give national roll-ups for a **50-million-person** baseline.

2.1 Scope, Units, and Time Horizon

- **Geography and unit.** Global defaults; no focal region. Outputs per-capita and per 1,000 people; national synthesis at 50M.
- **Time horizon. Present technology** only: techniques in commercial use or late deployment.
- **Population structure.** Generic per-capita baselines; age-structure effects handled in sensitivity runs.

2.2 Service Floors and Quality Safeguards

We use **sufficiency-first** floors. Hours are minimized *subject to* these floors and explicit safety/reliability KPIs.

- **Food.** ≥2,300–2,600 kcal/person/day; balanced macro/micro; cold-chain integrity; food-safety conformance near 100%.
- **Housing.** ≥15–25 m^2/person habitable; thermal comfort (e.g., 20–26°C, 40–60% RH) for most occupied hours; code compliance; ≥95% annual maintenance completion.
- **Healthcare.** Universal primary registration; timely access; safe staffing to WHO-type ratios; essential medicines availability very high.
- **Education & university.** Universal primary–secondary; ratio floors by level; guaranteed access to undergraduate teaching; **Research** baseline capacity (public labs, core technical staff) to sustain sectoral innovation.
- **Water.** ≥50–100 L/person/day potable; SDG quality (0 E. coli/100 ml); high supply uptime; leakage targets.
- **Sanitation.** 100% safe containment and treatment; compliant effluents; managed sludge chains.
- **Energy (power, heat, cooking).** Household electricity adequacy; reliability (SAIDI/SAIFI); universal clean cooking; backup for critical loads.
- **Mobility.** Baseline access by public transit and active modes; frequency floors by density; on-time performance high.
- **Digital.** Broadband downlink at useful baseline (e.g., 10–25 Mbps); low latency; public digital services coverage; high uptime.
- **Industrial staples.** Per-capita sufficiency bundles; durability/repairability standards; low defect and strong warranty fulfillment.
- **Culture & libraries.** Public libraries, cultural venues, and programming hours per 1,000 residents; preservation and access KPIs.

- **Leisure & local travel.** Baseline access to parks, sports, and regional leisure mobility; safety and reliability floors.

Binding rule. Quality and safety KPIs are hard constraints, not tradeables.

2.3 Equity Targets and Care Work

- **Universal coverage with parity.** Floors apply to everyone; regional parity enforced by quantile targets over the plan horizon.
- **Care work counted.** Child/elder/disability/community care is in the time budget; a professionalized share is paid, the rest supported by public services and time credits.
- **Fair time distribution.** Rotate unpleasant tasks; automate high-drudgery functions first.

2.4 Ecological Ceilings

Per-capita ceilings constrain materials footprints, land and water withdrawals, and CO_2e in line with minimum °C pathways. Sector models must meet service floors *within* these ceilings; when tight, select lower-impact techniques even if they shift labor, then re-minimize total hours under constraints.

2.5 Automation Scenarios (Sector-Specific)

- **Low.** Median current practice; manual-heavy; fragmented admin.
- **Medium.** Best-practice mainstream; semi-automation; digital scheduling; preventive maintenance.
- **High.** Frontier techniques commercially deployed (e.g., robotic harvest where feasible; lights-out-capable cells; autonomous material handling; advanced orchestration).

Scenarios are **policy choices**, not gadget showcases. Each is evaluated against the same floors and ceilings.

3 Planning Food As A Public Service

We can provision tasty, healthy food every day of the year with fewer human hours than today. This chapter fixes service floors, excludes harmful techniques by rule, counts direct and indirect hours, and minimizes necessary labor while holding quality constant.

Picture a city of one thousand people. Community kitchens serve three hot meals daily. A reliable cold chain brings fresh produce. Prep, cooking, and sanitation follow strict protocols; repetition is automated; variety comes from modular recipes and batch finishing. The labor footprint is small and the food is healthy.

Organization and technology are the levers. Modern mechanization on farms, consolidated post-harvest flows, and mixed central–satellite kitchens cut hours per meal. Planning makes those hours visible and sharable as shorter workweeks.

We already can grow food with very low farm-gate labor. Mechanization collapses hours per person-year: about ∼1.9 for a basic mechanized diet and ∼4.7 for an affluent mechanized diet; adding labor-intensive imports like coffee and fruit from non-mechanized systems can raise this to ∼50, while fully non-mechanized systems require ∼375–963 *hours/year/person*.[1]

Scope, Floors, and Exclusions

- **Scope.** Global default; one unit is 1,000 residents. Outputs are **weekly hours per 1,000 people**.
- **Service floors.** Three nutritious meals per person per day, 365 days. Baseline diet: 2,500 kcal/person/day with balanced macro and adequate micronutrients.[2] Variety is enforced by menu design, not extra manual steps.
- **Exclusions.** No air-freighted perishables; no coal-heated greenhouses; no routine deforestation crops; no unsafe antibiotic use in animal chains. Hours here are a minimum under clean techniques.
- **Labor boundary.** Direct + indirect hours: field work, equipment maintenance implied by output, post-harvest handling, warehousing, linehaul and last-mile, kitchen prep, cooking, service, sanitation, HACCP checks, dishwashing.
- **Kitchens model.** Mixed system: central production for efficient batch/cook-chill where quality allows; satellite finishing for freshness and texture. Standards target nutritional adequacy and chef-level taste.

Calculation log (food, per 1,000 residents)

Inputs

- **Meals/week.** $1{,}000 \times 3 \times 7 = 21{,}000$.
- **Energy floor.** 2,500 kcal/person/day.[3]

[1] Scope limited to work up to the farm gate; excludes processing, transport, retail, and cooking. See [(1)].
[2] FAO/WHO/UNU requirement ranges; we adopt the upper adult band for conservatism [(2)].
[3] See [(2)].

Coefficients

	Low	Medium	High
Kitchen productivity, meals per labor hour (MPLH)	12[1]	25[2]	45[3]
Farm labor, hours/week/1,000	7,200–18,500[4]	960[5]	90[6]
Logistics labor, hours/week/1,000	90–180	90–180	90–180

Notes. Logistics band sized from person-to-goods case-pick rates and route hours; travel dominates order picking, so pick density is the main lever.[4]

Compute

$$\text{KitchenHours} = \frac{21{,}000}{\text{MPLH}} = \{\,21{,}000/12,\;\; 21{,}000/25,\;\; 21{,}000/45\,\} = \{\,1{,}750,\;\; 840,\;\; 467\,\}.$$

$$\text{FarmHours} \in \{\,7{,}200\text{–}18{,}500,\;\; 960,\;\; 90\,\}, \qquad \text{LogisticsHours} \in [90,\; 180].$$

Summary (weekly hours per 1,000)

Table 3.1: Weekly human hours per 1,000 residents (food system).

Scenario	Farming	Logistics	Kitchens	Total
Low automation	7,200–18,500	90–180	1,750	9,040–20,430
Medium automation	960	90–180	840	1,890–1,980
High automation	90	90–180	467	647–737

These totals hold service floors and safety/reliability constraints fixed. Organization and technique choice move results along the scenario bands; the plan selects mixes that meet ecological ceilings while minimizing total human hours.

[1] Institutional on-site MPLH commonly in the mid-teens; 12 is a conservative lower bound [(3), (4), (5)].

[2] Mainstream best practice with assisted prep and line balance; conservative midpoint consistent with institutional KPI ranges [(3), (4)].

[3] Central production with cook–chill and satellite finishing; capped below higher industry claims to remain conservative [(6)].

[4] Manual tasks dominate at low mechanization; FAO notes hand-weeding ∼140 h/ha on first pass (lower on subsequent passes), supporting a wide low band [(7)].

[5] Derived from ∼50 h/person-year when some imports are non-mechanized [(1)]; $50 \times 1000/52 \approx 960$.

[6] Mechanized low end; field budgets of a few labor-hours/acre including maintenance and travel imply low single-digit hours per capita per year for staples [(8)].

[4] Raising pick density increases picks per person-hour [(9)]. Optimized manual zones can reach ∼150–250 cases/hour; we keep a conservative band [(10)].

4 Housing and Infrastructure Build, Retrofit, Maintain

We can deliver good housing with fewer hours by industrializing construction, standardizing details, and prioritizing envelopes that stay safe in heat waves and outages. The levers are design for manufacture and assembly (DfMA), airtight and insulated shells with heat recovery ventilation, and preventive maintenance planned on cycles that minimize rework. Hours fall without lowering comfort. Comfort is enforced by standards, not wishes.

4.1 Scope, Floors, and Guardrails

- **Scope.** Global default; unit of analysis is 1,000 residents. Output metric: **weekly human hours per 1,000 people**, including indirect hours embodied in inputs.
- **Service floors.** Habitable space 15–25 m^2/person with thermal comfort per widely used standards and verified ventilation. Target indoor conditions follow accepted comfort ranges over occupied hours.[1]
- **Climate and resilience guardrails.** New and retrofit shells achieve high efficiency and passive survivability. Airtightness targets: $n_{50} \leq 0.6\,\mathrm{h}^{-1}$ new build and $\leq 1.0\,\mathrm{h}^{-1}$ deep retrofit (EnerPHit), verified by blower-door tests.[2] Balanced mechanical ventilation with heat recovery (MVHR) meets residential ventilation codes and component performance tests.[3] Passive survivability is a design constraint: maintain safe indoor conditions for multi-day outages during heat and cold events.[4]
- **Exclusions.** No fossil boiler lock-in in new build. No envelope choices that create chronic overheating without mitigation. No assemblies that preclude repair. If a cleaner option increases labor, we accept the higher hours.
- **Labor boundary.** Direct on-site hours, factory hours embodied in prefabricated elements, commissioning/inspection, and scheduled maintenance. Indirect hours in major inputs (e.g., manufactured HVAC, windows) are included via coefficients.

4.2 Stock–Flow Baseline

We treat the building stock as a flow problem for a community of 1,000 residents:

$$\begin{aligned} A_{\text{floor}} &= \text{per-capita habitable m}^2 \times 1{,}000, \\ \alpha_{\text{new}} &= \text{annual new-build share of } A_{\text{floor}}, \quad \alpha_{\text{retro}} = \text{annual deep-retrofit share of } A_{\text{floor}}, \\ A_{\text{new,yr}} &= \alpha_{\text{new}}\, A_{\text{floor}}, \quad A_{\text{retro,yr}} = \alpha_{\text{retro}}\, A_{\text{floor}}. \end{aligned}$$

[1] Thermal comfort methods and limits per ASHRAE 55 and current addenda; see also EN 16798-1 for indoor environmental input parameters and TM59 methodology for overheating in homes [(11), (12), (13), (14)].

[2] Passive House new-build criterion $n_{50} \leq 0.6\,\mathrm{h}^{-1}$; EnerPHit retrofits target $n_{50} \leq 1.0\,\mathrm{h}^{-1}$ [(15), (16), (17), (18)].

[3] Rates per ASHRAE 62.2; unit performance EN 13141-7; PHI component criteria provide verified performance data [(19), (20), (21)].

[4] DOE and RMI summarize passive survivability and hours-of-safety metrics; super-efficient envelopes extend safe hours during outages [(22), (23), (24), (25)].

Guidance. Set A_{floor} from the chosen service floor (e.g., $20\,\text{m}^2$/person $\Rightarrow$ 20,000 m^2). Choose α_{retro} to reach the airtight/insulation targets within the plan horizon (e.g., 3–5%/yr for a 20–30 yr cycle). Choose α_{new} from population growth and replacement policy.[5]

4.3 Process Map

Three layers:

1. **Build:** site prep, foundations, structure, envelope, services, finishes; off-site fabrication where feasible.
2. **Retrofit:** envelope upgrades (insulation, airtightness, windows), MVHR, heat-pump conversion, thermal-bridge remediation.
3. **Maintain:** planned inspections, filter changes, cleaning, minor repairs, periodic replacements on RCM cycles.

Industrialization levers:

- Off-site modular/panelized systems reduce on-site hours and rework.[6]
- Standardized airtight/thermal-bridge-free junction details avoid call-backs.[7]
- Commissioning checklists for MVHR and heat pumps ensure performance in use.[8]

Calculation log (housing, per 1,000 residents)

All hours are weekly per 1,000 residents. Conservative rule: when ranges exist, use the higher labor figure.

Inputs

$$A_{\text{floor}} = 25\ \text{m}^2/\text{person} \times 1{,}000 = 25{,}000\ \text{m}^2.$$

Annual shares (global defaults, policy-credible): $\alpha_{\text{new}} = 1\%$ and $\alpha_{\text{retro}} = 3\%$.[9]

$$A_{\text{new,yr}} = 250\ \text{m}^2/\text{yr}, \qquad A_{\text{retro,yr}} = 750\ \text{m}^2/\text{yr}.$$

Coefficients (labor hours per m^2)

New build c_{new}. Anchor on multifamily requirements: 65 on-site and 164 economy-wide employee-hours per 100 ft^2 (on-site + upstream) [(36)]. With 100 ft^2 = 9.2903 m^2:

$$c_{\text{new, total}} \approx \frac{164}{9.2903} = 17.6, \quad c_{\text{new, on}} \approx \frac{65}{9.2903} = 7.0, \quad c_{\text{new, up}} \approx 10.6\ \text{h}/\text{m}^2.$$

Off-site practice typically reduces on-site labor by 20–40% or more [(35)]. Set

$$c_{\text{new, med}} \approx 10.6 + 0.75 \times 7.0 = 15.9, \quad c_{\text{new, high}} \approx 10.6 + 0.60 \times 7.0 = 14.8\ \text{h}/\text{m}^2.$$

[5] New dwellings ~0.7–1% of stock/yr in recent EU/OECD data; we adopt 1% to be conservative [(26), (27)]. Deep energy renovation rates are ~0.2% within ~1% overall; EU policy aims to at least double rates; analytical calls target ~3% deep/yr [(28), (29), (30)].

[6] Modular methods can accelerate timelines 20–50% and reduce on-site labor via parallelization and factory QA [(31), (32), (33), (34), (35)].

[7] Contractor and airtightness guides show sequencing to achieve $n_{50} \leq 0.6\,\text{h}^{-1}$ [(17), (18)].

[8] Frameworks: EN 13141-7 and PHI component criteria [(20), (21)].

[9] See sources cited above for stock flow anchors [(26), (27), (28), (29), (30)].

Deep retrofit c_{retro} (EnerPHit-level envelope/airtightness). Evidence of ∼19 direct jobs per €1 M invested [(37)] with 1 job-year = 1,800 h gives 34,200 h per €1 M. Deep-retrofit program costs ∼ £450–€650/m² [(38), (39)]. Taking €600/m²:

$$\frac{34{,}200}{1{,}000{,}000/600} \approx 20.5 \text{ h/m}^2.$$

Prefabricated panels (Energiesprong-type) shorten on-site work [(40), (35)]. Set

$$c_{\text{retro, low}} = 20, \quad c_{\text{retro, med}} = 14, \quad c_{\text{retro, high}} = 10 \text{ h/m}^2,$$

with retrofit airtightness target $n_{50} \leq 1.0\,\text{h}^{-1}$ [(41), (42)].

Maintenance m_{annual}. Facility benchmarks show ∼1.9 FTE/10,000 m² (2,080 h/yr basis) [(43)] and ∼1 FTE/50,000 ft² (≈4,645 m²) [(44)]. Conservative aggregate:

$$m_{\text{annual}} = 0.50 \text{ h/m}^2\text{/yr}.$$

Compute

Annual hours:

$$H_{\text{new,yr}} = c_{\text{new}}\, A_{\text{new,yr}}, \quad H_{\text{retro,yr}} = c_{\text{retro}}\, A_{\text{retro,yr}}, \quad H_{\text{maint,yr}} = m_{\text{annual}}\, A_{\text{floor}}.$$

Weekly per 1,000: $H_{\bullet,\text{week}} = H_{\bullet,\text{yr}}/52$.

Numbers. With $A_{\text{new,yr}} = 250\,\text{m}^2$, $A_{\text{retro,yr}} = 750\,\text{m}^2$, $A_{\text{floor}} = 25{,}000\,\text{m}^2$:

$$H_{\text{new,week}} = \left\{ \frac{17.6 \times 250}{52} = 84.6,\ \frac{15.9 \times 250}{52} = 76.4,\ \frac{14.8 \times 250}{52} = 71.2 \right\},$$
$$H_{\text{retro,week}} = \left\{ \frac{20 \times 750}{52} = 288.5,\ \frac{14 \times 750}{52} = 201.9,\ \frac{10 \times 750}{52} = 144.2 \right\},$$
$$H_{\text{maint,week}} = \frac{0.50 \times 25{,}000}{52} = 240.4 \quad \text{(all scenarios)}.$$

Summary (weekly hours per 1,000)

Scenario	Build	Retrofit	Maintain	Total
Low	85	288	240	613
Medium	76	202	240	518
High	71	144	240	455

Notes. (i) New-build coefficients include upstream embodied labor per [(36)]. (ii) Retrofit coefficients target EnerPHit-level envelope/airtightness [(41), (42)]. (iii) Maintenance excludes cleaning/grounds; it covers base building maintenance staffing. (iv) Shares $\alpha_{\text{new}}, \alpha_{\text{retro}}$ can be swapped for local plans; the formulas above hold.

5 Utilities As A Public Service
Energy, Water, Sanitation, Digital — Operate and Maintain

5.1 Scope, Floors, and Guardrails

- **Electricity (floor).** 24/7 household supply; reliability tracked by SAIDI/SAIFI per IEEE 1366.[1]
- **Water (floor).** Continuous potable supply meeting WHO guidelines.[2]
- **Sanitation (floor).** Full collection and treatment meeting effluent standards (UWWTD-style for urban systems).[3]
- **Digital (floor).** Fixed broadband to all dwellings; baseline access with high uptime.[4]
- **Exclusions.** No coal plants or diesel peakers where clean options exist; no chronic leakage tolerance; no treatment bypass. If a cleaner practice raises hours, we accept the higher hours.
- **Labor boundary.** Operations, maintenance, control rooms, field crews, labs/QA, customer service; upstream indirect hours (spares/equipment) included via conservative coefficients.

5.2 Process Map

1. **Electricity distribution:** substation O&M (Operations and Maintenance), line patrol, vegetation management, metering, outage response.

2. **Water supply:** treatment O&M, storage, network monitoring, leakage control, water-quality labs.

3. **Wastewater:** collection O&M, pump stations, treatment plant operations, compliance sampling.

4. **Digital:** access network O&M, CPE provisioning, NOC monitoring, outside-plant repairs.

Calculation log (utilities, per 1,000 residents)

Inputs

Average household size $s_{\text{hh}} = 2.5$ persons/household (OECD range).[5]

$$\text{Households} = \frac{1{,}000}{s_{\text{hh}}} = 400.$$

[1]IEEE 1366 defines SAIDI/SAIFI and reporting practice [(45), (46)].
[2]WHO *Guidelines for drinking-water quality*, 4th ed. with addenda [(47), (48)].
[3]EU Urban Waste Water Treatment Directive 91/271/EEC as benchmark [(49), (50)].
[4]Use national definitions; ITU tracks fixed broadband adoption; SLAs set locally [(51)].
[5]OECD Family Database SF1.1 shows many OECD countries near 2.4–2.6; we adopt 2.5 [(52), (53)].

Allowance for small non-residential/public connections: +10% (conservative). Per-utility retail accounts:

$$C_{\bullet} = 400 \times 1.10 = 440, \qquad C_{\mathrm{W\&WW}} = 2 \times 440 = 880 \text{ (combined water+sewer)}.$$

Coefficients

Electricity (customers per non-generation employee). Public-power benchmarking: median 325 cust/emp; quartiles 264 (Q1) and 422 (Q3).[6]

$$\text{Low} = 264, \quad \text{Med} = 325, \quad \text{High} = 422 \ \ \text{cust/emp}; \quad \text{weekly hours} = 40.$$

Water & wastewater (staff per 1,000 connections). IBNET/World Bank: ~ 0.8 staff/1,000 connections in high-income; many developing systems < 3; laggards higher.[7]

$$\text{Low} = 3.0,\ \text{Med} = 1.5,\ \text{High} = 0.8 \ \ \text{staff/1,000 conn}; \quad \text{weekly hours} = 40.$$

Digital (employees per 1,000 customers, fixed access). Independent benchmarking trend: $\sim 8 \rightarrow 5.8$ emp/1,000 customers (2016–2024).[8]

$$\text{Low} = 8.0,\ \text{Med} = 6.7,\ \text{High} = 5.8 \ \ \text{emp/1,000 cust}; \quad \text{weekly hours} = 40.$$

Compute

Electricity. $E_{\text{elec}} = \dfrac{C_{\text{elec}}}{\text{cust/emp}}, \quad H_{\text{elec}} = 40\, E_{\text{elec}}.$

$$\text{Low: } 440/264 = 1.667 \Rightarrow 66.7; \quad \text{Med: } 440/325 = 1.354 \Rightarrow 54.2; \quad \text{High: } 440/422 = 1.043 \Rightarrow 41.7.$$

Water + wastewater (combined). $E_{\mathrm{W\&WW}} = \dfrac{C_{\mathrm{W\&WW}}}{1{,}000} \times (\text{staff}/1{,}000), \quad H_{\mathrm{W\&WW}} = 40\, E_{\mathrm{W\&WW}}.$

$$\text{Low: } 0.88 \times 3.0 = 2.64 \Rightarrow 105.6; \quad \text{Med: } 0.88 \times 1.5 = 1.32 \Rightarrow 52.8; \quad \text{High: } 0.88 \times 0.8 = 0.704 \Rightarrow 28.2.$$

Digital. $E_{\text{dig}} = \dfrac{C_{\text{dig}}}{1{,}000} \times (\text{emp}/1{,}000), \quad H_{\text{dig}} = 40\, E_{\text{dig}}.$

$$\text{Low: } 0.44 \times 8.0 = 3.52 \Rightarrow 140.8; \quad \text{Med: } 0.44 \times 6.7 = 2.948 \Rightarrow 117.9; \quad \text{High: } 0.44 \times 5.8 = 2.552 \Rightarrow 102.1.$$

Summary (weekly hours per 1,000 residents)

Scenario	Electricity	Water&WW	Digital	Total
Low	67	106	141	314
Medium	54	53	118	225
High	42	28	102	172

[6] APPA *Financial and Operating Ratios of Public Power Utilities*, "Retail Customers per Non-power-generation Employee" [(54)].

[7] World Bank/IBNET synthesis and definitions [(55), (56)]; recent regional benchmarks show declines with performance programs [(57)].

[8] Moss Adams Telecom Benchmarking Studies [(58), (59), (60)].

Notes. Standards: IEEE 1366 for SAIDI/SAIFI; WHO GDWQ for drinking water; UWWTD-style effluent limits; ITU fixed-broadband context.[9] Household size from OECD; +10% non-residential allowance conservative.[10] Staffing/productivity anchors: APPA customers-per-employee for electricity; IBNET staff-per-connection for water/wastewater; Moss Adams employees-per-1,000 customers for fixed broadband.[11]

[9] IEEE 1366 overview [(45)]; EIA reliability glossary [(46)]; WHO GDWQ [(47), (48)]; UWWTD [(49), (50)]; ITU fixed broadband [(51)].
[10] OECD SF1.1 [(52), (53)].
[11] APPA ratios [(54)]; IBNET and regional benchmarks [(55), (56), (57)]; telecom benchmarking [(58), (59), (60)].

6 Care and Learning

A decent life needs universal primary care and universal schooling. The lever is not rushing clinic visits or cramming classrooms. The lever is *staffing to sufficiency* for clinical and teaching time while cutting non-value administrative load with standard workflows and digital tools. We treat clinical contact time and classroom time as *hard constraints*. We minimize hours only in scheduling, records, and logistics.

6.1 Scope, Floors, and Boundaries

Floors.

- *Healthcare*. Workforce floor meets WHO's UHC threshold of **4.45** physicians+nurses+midwives per 1,000 people[1] with adequate contact time: OECD reports a mean ∼6 physician consultations/person/year[2] and primary-care consult lengths commonly in the 10–15 min range[3]. We hold quality by not compressing these.
- *Education*. Universal primary and lower-secondary with typical student–teacher ratios around 25:1 (primary) and 20:1 (lower secondary)[4]. Compulsory instruction time averages ∼805 h/year (primary) and ∼916 h/year (lower-secondary)[5].

Population structure. For a global default without age disaggregation, we conservatively set school-age share at **20**% of population[6].

Labor boundary. Direct + indirect hours inside clinics and schools (clinical/teaching + support, scheduling, records, supervision). Facilities cleaning and building maintenance are counted in *Housing & Infrastructure*. Utilities and networks are counted in *Energy–Water–Sanitation–Digital*.

Calculation log (care & learning, per 1,000 residents)

Inputs

$$
\begin{aligned}
\text{Population} &= 1{,}000, \\
\text{SchoolAgeShare} &= 0.20 \Rightarrow \text{Students} = 200.
\end{aligned}
$$

Conservative coefficients and rules

- *Healthcare clinical floor*: 4.45 physicians+nurses+midwives per 1,000⇒ clinical FTE = 4.45. Weekly hours per FTE = 40. Clinical hours floor = $4.45 \times 40 = \mathbf{178}$ h/wk/1,000.[7]

[1] World Health Organization [(61)]; see also **WHO-AFRO-Threshold**, Scheil-Adlung et al. [(62)].
[2] OECD [(63)].
[3] Irving [(64)].
[4] World Bank, UNESCO UIS pupil–teacher ratio indicators [(65), (66)].
[5] OECD [(67)].
[6] Children 0–14 are ∼24.7% globally in 2024; we use 20% to avoid overstating student counts [(68)].
[7] World Health Organization [(61)].

- *Allied floor*: add pharmacists/dentists and other core cadres; literature median yields ~51.2 per 10,000 across five occupations[8]. Conservatively add 0.67 FTE/1,000 ($\approx 51.2 - 44.5$ per 10,000) $\Rightarrow 0.67 \times 40 = \mathbf{27}$ h/wk.
- *Healthcare admin/support multiplier* (records, scheduling, IT helpdesk, supervision): evidence places admin at 15–30% of spending in high-income systems[9]. For labor, set fractions of clinical+allied hours:
$$\text{Low} = 50\%\,, \quad \text{Medium} = 25\%\,, \quad \text{High} = 15\%.$$
- *Education teacher ratio*: blended effective ratio **22:1** (between 25:1 primary and 20:1 lower secondary)[10] $\Rightarrow$ Teacher FTE $= 200/22 = 9.09$.
- *Teacher weekly hours*: set at 40 to include contact, prep, collaboration[11].
- *Education admin/support multiplier* (school admin, registrars, guidance, data):
$$\text{Low} = 40\%\,, \quad \text{Medium} = 25\%\,, \quad \text{High} = 15\%.$$[12]
- *Conservative rule*: when sources differ, choose the higher labor figure; never reduce clinical or classroom time to "save" hours.

Compute: healthcare

$$\text{ClinicalHours} = 178 \quad ; \quad \text{AlliedHours} = 27 \quad ; \quad \text{BaseClinical+Allied} = \mathbf{205}.$$

$$\text{AdminHours} = \begin{cases} 0.50 \times 205 = 102.5 & \text{Low} \\ 0.25 \times 205 = 51.3 & \text{Medium} \\ 0.15 \times 205 = 30.8 & \text{High} \end{cases} \Rightarrow \quad \text{HealthcareTotal} = \begin{cases} \mathbf{308} \\ \mathbf{256} \\ \mathbf{236} \end{cases} \text{h/wk/1,000 (rounded).}$$

Compute: education

$$\text{TeacherFTE} = \frac{200}{22} = 9.09\,, \quad \text{TeacherHours} = 9.09 \times 40 = \mathbf{364}.$$

$$\text{Admin\&Support} = \begin{cases} 0.40 \times 364 = 146 & \text{Low} \\ 0.25 \times 364 = 91 & \text{Medium} \\ 0.15 \times 364 = 55 & \text{High} \end{cases} \Rightarrow \quad \text{EducationTotal} = \begin{cases} \mathbf{510} \\ \mathbf{455} \\ \mathbf{419} \end{cases} \text{h/wk/1,000.}$$

Summary (weekly hours per 1,000)

Scenario	Healthcare	Education	Total	Notes
Low automation	308	510	**818**	Paper-heavy admin in both sectors.
Medium automation	256	455	**711**	Digital records, scheduling, basic workflow.
High automation	236	419	**655**	Full e-records, auto-scheduling...

Notes. Clinical floor from WHO UHC 4.45/1,000 [(61)]; consult volumes and lengths from OECD and primary-care reviews [(63), (64)]. Allied addition from global workforce synthesis [(69)]. Education ratios and instruction time from World Bank/UNESCO/OECD [(65), (66), (67)]. Admin burdens from comparative health and education evidence [(70), (71), (72), (73), (74), (75)].

[8] Liu et al. [(69)].
[9] Gee [(70)], Himmelstein and Woolhandler [(71)], and Tracker) [(72)].
[10] World Bank Open Data [(65)] and UNESCO Institute for Statistics [(66)].
[11] OECD TALIS shows substantial non-teaching time; we cap at 40 for conservatism [(73), (74)].
[12] OECD [(73), (74), (75)].

7 Research and Higher-Degree Education

7.1 Scope, Floors, and Exclusions

Service floors. Research intensity at or above advanced-economy norms, delivered as *researchers per 1,000 inhabitants* and matched graduate capacity. We anchor to official indicators of researchers per million[1] and recent levels in the EU and top performers.[2]

Exclusions. No reliance on precarious over-enrolment, no routine unpaid overtime as a planning assumption, no administrative offloading to researchers beyond a conservative 10–20% of their time at medium/high scenarios.[3]

Labor boundary. Direct and indirect hours: researchers, graduate teaching and supervision, laboratory technicians, core-facility staff, research administrators, IT/library support.

7.2 Process Map and Variables

Four layers:

1. **Research production** (principal investigators, postdocs, research staff).
2. **Graduate education** (Master's and doctoral coursework; supervision).
3. **Shared infrastructure** (core facilities, HPC, libraries, research IT).
4. **Administration and compliance** (pre-/post-award, ethics, data, safety).

Core stock variables per 1,000 residents (inputs to hours):

- Researchers per 1,000 residents (floor set by scenario).[4]
- Graduate students per 1,000 residents (Master's, PhD).[5]
- Student-to-staff ratio in tertiary teaching. We adopt 12:1 for graduate *coursework* to stay conservative vs OECD tertiary average ∼16:1.[6]
- Doctoral supervision load policy. Cap near 5–6 doctoral candidates per primary supervisor cluster, consistent with sector guidance.[7]

[1] UNESCO SDG 9.5.2 defines "Researchers (FTE) per million inhabitants" and the Frascati basis for R&D personnel accounting. [(76)]

[2] EU counted 2.15 million researchers (FTE) in 2023 with growth since 2013; distribution by sector is reported by Eurostat. [(77)] Countries such as Israel and Korea exceed 7,000 researchers per million. [(78), (79)]

[3] Faculty burden surveys report large shares of time diverted to compliance and grant administration; we plan explicit administrator FTEs to reverse this. [(80), (81)]

[4] Global indicator and top-quartile reference values compiled by UNESCO/Eurostat/OWID. [(76), (77), (79)]

[5] EU had 18.8 million tertiary students in 2023. With ∼449–450 million inhabitants, that is ∼42 students per 1,000 residents; doctoral shares of total tertiary students range from ∼2–6% in large EU systems. [(82), (83)]

[6] OECD *Education at a Glance* reports tertiary student-to-staff averages around the mid-teens. We use a tighter 12:1 for graduate coursework. [(84)]

[7] Surveys and guidance place typical primary-supervisor loads around 3–6 candidates; many institutions cap between 6 and 8. [(85), (86)]

- Technician, core, IT/library support ratios per researcher.[8]
- Administrative offset. Dedicated research administrators to cut faculty admin time from ∼40% burdened levels to 10–25%.[9]

Calculation log (research & graduate education, per 1,000 residents)

Inputs by scenario

Researchers per 1,000 residents:

$$\{\text{Low},\ \text{Med},\ \text{High}\} = \{3,\ 6,\ 8\}.$$

These correspond to 3,000, 6,000, and 8,000 researchers per million, spanning OECD/EU norms up to top-quartile countries.[10]

Graduate enrolment per 1,000 residents (Master's, PhD):

$$\{\text{M},\ \text{D}\}_{\text{Low,Med,High}} = \{(8,\ 1.5),\ (10,\ 2.0),\ (12,\ 3.0)\}.$$

Within EU density implied by ∼42 tertiary students per 1,000 people with 2–6% doctoral shares.[11]

Coefficients (conservative)

- Technician ratio (per researcher): Low 0.20; Med 0.35; High 0.50.[12]
- Core-facility staff (per researcher): Low 0.08; Med 0.12; High 0.15.[13]
- IT/library support (per researcher): Low 0.05; Med 0.06; High 0.07.[14]
- Graduate coursework staffing: student-to-staff 12:1; PhD coursework counted at 0.5 of a Master's course-load.[15]
- Research administration offset: model added admin FTEs as 0.30 per researcher (Low), 0.25 (Med), 0.20 (High), plus 0.02 per graduate student for program tasks.[16]

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[8] UNESCO tracks technicians-per-million; high-income exemplars show technicians at 10–30% of researcher headcount, while core facility frameworks argue for central technical staffing. We choose conservative-to-generous ratios to remove friction. [(78), (87), (88)]

[9] Faculty burden studies: ∼42% of *research time* lost to admin in U.S. federal funding contexts; GAO reviews persistent compliance workload. [(80), (81)]

[10] EU/EFTA clusters near 3,000–5,000; Israel/Korea >7,000 per million. [(77), (78), (79)]

[11] Derived from EU totals and doctoral shares. [(82), (83)]

[12] Anchored to UNESCO technicians-per-million indicator and core-facility practice; we choose the upper band to reduce PI friction. [(78), (87), (88)]

[13] Centralized cores concentrate expertise; staffing scales with instrument portfolio and user base. [(89), (88)]

[14] Covers ELN/LIMS, HPC, repositories, data management; scaled to research intensity. [(90)]

[15] OECD tertiary student-to-staff averages ∼16:1; 12:1 is a conservative quality floor for graduate teaching. [(84)]

[16] Based on FDP/GAO evidence of large admin shares; explicit offsets make the burden visible and removable. [(80), (81)]

Formulas

Let 40 be hours/FTE/week. For scenario s:

$$\begin{aligned}
\text{Researchers}_s &= r_s \\
\text{Technicians}_s &= r_s \times \tau_s \\
\text{TeachingFTE}_s &= \frac{\text{Master}_s + 0.5\,\text{PhD}_s}{12} \\
\text{AdminFTE}_s &= r_s \times a_s + 0.02 \times (\text{Master}_s + \text{PhD}_s) \\
\text{CoreFTE}_s &= r_s \times c_s \\
\text{ITLibFTE}_s &= r_s \times i_s + 0.01 \times (\text{Master}_s + \text{PhD}_s) \\
H_s &= 40 \times (\text{Researchers}_s + \text{Technicians}_s + \text{TeachingFTE}_s + \text{AdminFTE}_s + \text{CoreFTE}_s + \text{ITLibFTE}_s).
\end{aligned}$$

Summary (weekly hours per 1,000)

Scenario	Researchers	Technicians	Teaching	Admin	Core	IT/Lib	Total
Low	120	24	29	44	10	10	236
Medium	240	84	37	70	29	19	478
High	320	160	45	76	48	28	677

Notes. Floors use UNESCO/Eurostat researcher densities and EU tertiary enrolment anchors [(76), (77), (82), (79)]. Technician/core/IT ratios follow core-facility best practice and UNESCO technician data [(88), (89), (78)]. Admin offsets explicitly resource compliance to reduce faculty burden per FDP/GAO [(80), (81)]. Graduate teaching sized at 12:1 to stay conservative vs OECD averages [(84)]; supervision caps follow UKCGE guidance [(85), (86)].

8 Mobility and Distribution

8.1 Scope, Floors, and Exclusions

Service floors.

- *Passenger mobility.* Scheduled public transport available 16 h/day, 7 days/week. Frequency and coverage on main corridors; reliability per TCQSM (schedule adherence and headway regularity).[1] Average surface bus scheduled speed 12.3 mph (19.8 km/h) for conversions.[2]
- *Urban freight (last mile).* Essential parcels delivered from micro-hubs. Baseline volume = 15 parcels/person/year as a conservative floor for essentials.[3]

Exclusions. No routine air-freight of urban parcels; no diesel trunking inside LEZ/ULEZ where clean options exist; no unsafe practices. Prefer electrified fleets and cargo bikes where feasible.

Labor boundary. Direct operating labor (vehicle operation, dispatch, supervision, station/customer roles), maintenance labor implied by scheduled service, cleaning, and micro-hub handling. Manufacturing hours for fleets and fixed guideway appear in the Industrial Staples chapter.

Calculation log (per 1,000 residents per week)

8.1.1 Passenger mobility — inputs and coefficients

- **Service supply**. Floor $\mathrm{VRH}_{\mathrm{wk}} = 40$ vehicle revenue hours/week per 1,000 residents.[4]
- **Layover/relief**. Pay-to-platform factor $f_p = 1.15$ to cover recovery, operator relief, limited deadhead.[5]
- **Speed**. Average bus speed $v = 12.3$ mph.[6]
- **Maintenance labor check**. Maintenance labor hours per 1,000 miles: diesel ~ 6, stabilized BEB ~ 3–4.[7]
- **Workforce share**. Vehicle operations $\sim 63\%$ of operating employees.[8]

8.1.2 Passenger mobility — computations

Operator hours.

$$H_{\mathrm{ops}} = \mathrm{VRH}_{\mathrm{wk}} \times f_p = 40 \times 1.15 = 46 \text{ operator h/wk.}$$

[1]Transit Capacity and Quality of Service Manual (TCQSM) 3rd ed. for frequency, coverage, reliability, recovery sizing. [(91)]
[2]APTA Fact Book reports average bus operating speeds near 12.3 mph. [(92)]
[3]Global parcel volume ~7 per person in 2022; high-intensity markets ~76–80. Floor set at 15 for essentials. [(93), (94)]
[4]VRH/capita is a standard supply metric (FTA NTD). We choose a conservative floor; agencies use similar thresholds in peer reviews. [(95), (96)]
[5]TCQSM recovery and terminal design imply pay hours > platform hours; 15% used conservatively. [(91)]
[6]APTA Fact Book. [(92)]
[7]NREL tracked fleets report maintenance *labor* hours/1,000 miles by tech. [(97)]
[8]National Academies guidance; used to scale ops to total operating hours (ops+maintenance+non-vehicle). [(98)]

Miles for maintenance envelope.

$$\text{Miles}_{\text{wk}} = \text{VRH}_{\text{wk}} \times v = 40 \times 12.3 = 492 \text{ mi/wk}.$$

Implied bus maintenance labor:

$$H_{\text{maint}} \approx \begin{cases} 492 \times 6/1000 \approx 3.0 \text{ h/wk} & \text{(diesel)} \\ 492 \times 4/1000 \approx 2.0 \text{ h/wk} & \text{(BEB stabilized)} \end{cases}$$

(We do not add this separately when using workforce-share scaling below.)

Scale to total operating hours. Let $s = 0.63$ be the operator share. Then

$$H_{\text{PT,total}} = \frac{H_{\text{ops}}}{s} = \frac{46}{0.63} \approx 73 \text{ h/wk}.$$

8.1.3 Passenger mobility — scenario adjustments

- **Low automation**. Surface bus only; conventional scheduling and fare collection. Use $H_{\text{PT,total}} = 73$.
- **Medium automation**. Same VRH_{wk} floor; all-door boarding, TSP, dispatch tools. Reduce f_p to 1.12 $\Rightarrow H_{\text{ops}} = 44.8$. Keep $s = 0.63 \Rightarrow H_{\text{PT,total}} \approx 71$.[9]
- **High automation**. Shift trunk share $p = 0.5$ to unattended train operation (UTO); empirical staff reduction $\sim$ 30–70% on UTO lines.[10] Effective operator hours $= 46(1 - 0.5p) = 34.5$. Keep non-operator hours as in low for conservatism. Total $\approx 34.5 + (73 - 46) = 61.5$ h/wk.

8.1.4 Urban freight (last mile) — inputs and coefficients

- **Parcels**. 15 parcels/person/year $\Rightarrow$ 15,000/year per 1,000 $\Rightarrow\approx$ 288/week.[11]
- **Drops per labor hour**. Vans 4–6; e-cargo bikes 7–10 in dense cores.[12]
- **Micro-hub handling**. Fixed overhead 10 h/wk (conservative) pending design.

8.1.5 Urban freight — computations

Route-delivery hours $H_{\text{deliv}} = \frac{\text{parcels/wk}}{\text{drops per labor hour}}$.

- **Low automation (diesel/e-van, manual planning)**: 5 drops/h $\Rightarrow H_{\text{deliv}} = 288/5 = 57.6$; +10 handling $\Rightarrow \boxed{68}$ h/wk.
- **Medium automation (e-van, optimized routing)**: 6 drops/h $\Rightarrow$ 48; +10 $\Rightarrow \boxed{58}$ h/wk.
- **High automation (e-cargo + micro-hubs)**: 8 drops/h $\Rightarrow$ 36; +10 $\Rightarrow \boxed{46}$ h/wk.

[9] ITS and better terminal design reduce excess pay hours for the same scheduled VRH. [(91)]
[10] Meta-analyses and UITP reports; we adopt 50% on the share p. [(99), (100)]
[11] Global average ~7; UK ~76–80; floor 15 for essentials. [(93), (94)]
[12] Independent London/Brussels studies; cargo bikes outperform vans on drops/h. [(101), (102), (103)]

Summary (weekly hours per 1,000)

Table 8.1: Weekly hours per 1,000 residents to meet mobility and essential last-mile floors.

Scenario	Passenger PT	Urban freight	Total
Low automation	73.0	68	141
Medium automation	71.0	58	129
High automation	61.5	46	108

9 Industrial Staples I: Clothing, Laundry, Repair

We guarantee a sufficient wardrobe, weekly laundering, and repair for fit and longevity with minimal necessary labor. The levers are standardization, line balance, and consolidation.

9.1 Scope, Floors, Exclusions

Service floors. Sufficient wardrobe maintained over time; weekly access to laundering for clothing and linens; guaranteed repair/alteration for fit, fasteners, and damage. Wardrobe sufficiency follows the Decent Living Standards framing (clothing as a basic good) and sufficiency literature[1].

Exclusions. We exclude harmful techniques. No incineration of returns as a throughput strategy; no forced overproduction; no coal-fired process heat. Labor coefficients are conservative; if a clean technique raises hours, we accept the higher hours.

Boundary. Direct + embodied indirect hours within: (i) garment manufacturing (cut–make–trim, finishing, QC); (ii) community laundry operations (wash/dry/finish/handling); (iii) repair/alteration. Upstream textile spinning/weaving is *not* counted here and is covered in the industrial inputs appendix; we note this to avoid double-counting.

Process map (clothing system)

1. *Make:* cut, sew, finish, inspect, pack.[2]
2. *Launder:* centralized wash/dry/iron/fold; KPI in kg per operator-hour.[3]
3. *Repair:* hems, seams, buttons, zipper replacement; extends life and reduces new throughput.[4]

Calculation log (per 1,000 residents)

Inputs and conservative choices

A. New garments per person-year. We adopt *12* new garments/person-year for the public provisioning baseline. Justification: WRAP reports typical lifespans of ∼3–4 years for tees/jeans and >6 years for coats,[5] which implies replacing roughly 15–25% of a wardrobe annually depending on mix. In addition, the "fair consumption space" pathway suggests as *low* as 5 new pieces/year if reuse/repair rise substantially; we keep 12 to be conservative on *labor hours*[6].

[1] Clothing appears explicitly as a material prerequisite in the Decent Living Standards framework [(104)]. Sufficiency wardrobes and low-purchase pathways are discussed in [(105)]. WRAP reports empirical garment lifetimes by type [(106)].

[2] Standard garment operations: cutting, sewing, finishing/pressing, inspection, packing [(107), (108)]. Sewing remains the most labor-dependent stage [(109)]; automation of soft-goods sewing is a frontier challenge [(110)].

[3] Industry benchmarks use PPOH/KPOH. Wash/dry/fold lines near ∼100 lb/operator-hour are cited as a good benchmark [(111)]; case studies show 42→57 lb/operator-hour improvement via workflow optimization [(112)].

[4] Repair and mending measurably extend lifetimes and displace purchases [(113), (106)].

[5] Jeans ∼4 years; T-shirts ∼4 years; coats/jackets >6 years in UK wardrobe studies [(106)].

[6] Five new items/year with stronger reuse is proposed as a 1.5°C-aligned consumption cap [(105)]. We use 12 to avoid underestimating labor.

B. Garment mix and sewing minutes (SAM). Representative annual mix per person:

5 basic knit tops, 3 trousers/jeans, 2 hoodies/sweaters, 1 jacket, 1 other.

Conservative standard minutes per piece (within published ranges): knit top 12 min; trouser/jean 35 min; hoodie/sweater 45 min; jacket 100 min; other 18 min.[7]

C. Overhead factor for cutting/finishing/QC. Apply 1.6× multiplier to sewing minutes to include cutting room, finishing/pressing, inspection, allowances.[8]

D. Laundry throughput. Assume 5 kg/person/week of clothing and linens.[9] Benchmarks in kg per operator-hour (KPOH):

- Low: 26 kg/operator-hour (57 lb/operator-hour).[10]
- Medium: 45.4 kg/operator-hour (100 lb/operator-hour).[11]
- High: 54.4 kg/operator-hour (120 lb/operator-hour).[12]

E. Repair/alteration allocation. 1.0 labor-hour/person-year to cover hems, buttons, seam re-stitching, zipper replacements.[13]

Step 1: Manufacturing hours

Annual sewing minutes per person:

$$M_{\text{min}} = 5 \cdot 12 + 3 \cdot 35 + 2 \cdot 45 + 1 \cdot 100 + 1 \cdot 18 = 373 \text{ min}$$

Apply overhead factor 1.6:

$$M_{\text{min,tot}} = 373 \times 1.6 = 596.8 \text{ min} = 9.95 \text{ h/person-year}$$

Weekly hours per 1,000 for medium automation:

$$H_{\text{make,med}} = \frac{9.95 \times 1{,}000}{52} = 191.3 \text{ h/week}$$

Scenario multipliers for line balance and assists: low = 1.20×, high = 0.70× (conservative caps).[14]

$$H_{\text{make,low}} = 229.6, \quad H_{\text{make,high}} = 133.9 \text{ h/week.}$$

Step 2: Laundry hours

Total weekly kg: $5 \cdot 1{,}000 = 5{,}000$ kg.

$$H_{\text{laundry}} = \frac{5{,}000}{\text{KPOH}} \Rightarrow \begin{cases} 192.3 & \text{low (26 kg/h)} \\ 110.1 & \text{med (45.4 kg/h)} \\ 91.9 & \text{high (54.4 kg/h)} \end{cases}$$

[7] Indicative SAM ranges compiled from practitioner tables and studies: basic tee/polo ∼8–15 min, shirts ∼20–25 min, five-pocket jeans/trousers ∼30–40 min, hoodies/sweaters ∼40–50 min, light jacket ∼80–120 min [(114), (115), (116)].

[8] Process breakdowns emphasize non-sewing operations; sewing is a large share of *cost* but not 100% of labor time [(107), (109)]. We use a conservative 60% sewing share ⇒ 1.6× factor on SAM to cover the rest.

[9] Service references suggest single-person weekly loads of ∼6–8 kg; family-of-four totals ∼26–30 kg/week [(117), (118), (119)]. We adopt 5 kg/person/week as a conservative planning floor.

[10] Case improvement from 42 to 57 lb/operator-hour in commercial laundry benchmarking [(112)].

[11] "Good" wash/dry/fold benchmark ∼100 lb/operator-hour [(111)].

[12] Industry commentary cites ∼120 lb/operator-hour as achievable with automation and optimized finishing; we cap at 120 for conservatism [(120)].

[13] Repair extends lifetime and reduces purchase flow [(113), (106)]. We assign a conservative 1 h/person-year to ensure availability.

[14] Line balancing routinely raises sewing output 15–30% [(121)]. We choose a modest 20% penalty for low and a 30% gain for high.

Step 3: Repair hours

$$H_{\text{repair}} = \frac{1.0 \text{ h/person-year} \times 1{,}000}{52} = 19.23 \text{ h/week}.$$

Totals

$$H_{\text{total}} = H_{\text{make}} + H_{\text{laundry}} + H_{\text{repair}}.$$

Summary (weekly hours per 1,000 residents)

Table 9.1: Clothing system hours: make, launder, repair. Conservative coefficients.

Scenario	Make	Laundry	Repair	Total
Low automation	229.6	192.3	19.2	441.2
Medium automation	191.3	110.1	19.2	320.6
High automation	133.9	91.9	19.2	245.1

10 Industrial Staples II: Household Goods & Appliances

10.1 Scope, Floors, Exclusions

Service floors. Each household has: refrigerator, clothes washer, safe cooktop/oven; small electrics (microwave or equivalent, vacuum, beverage maker); essential furniture kept functional. Household size set at 2.5 persons (median OECD range is 1.7–3.6; 2.5 is a conservative global default)[1].

Exclusions. No harmful techniques (e.g., coal-fired process heat, planned obsolescence). EU ecodesign durability and spare-part access are baseline for washers and similar[2]. Where repair increases labor but extends life, we accept the higher hours.

Boundary. Direct + indirect local hours for installation, field repair, bench refurbishment, minor assembly, and scheduling/QA overhead. Upstream component manufacturing, metals, plastics: counted elsewhere.

Calculation log (per 1,000 residents)

Inputs and conservative lifetimes

Households $H = \frac{1{,}000}{2.5} = 400$.

Major appliances per household: refrigerator (life 13 y), washer (10 y), cooktop/oven (15 y)[3]. Small electrics: microwave (9–10 y), vacuum (10 y), coffee machine (5.5–6.5 y)[4]. Furniture longevity: long-lived but variable; we budget a small annualized assembly/repair allowance[5].

Step A — Annual replacements → installs

$$\begin{aligned} \text{Fridges/year} &= 400/13 = 30.77, \quad t_{\text{install}} = 1.0 \text{ h} \\ \text{Washers/year} &= 400/10 = 40.00, \quad t_{\text{install}} = 1.5 \text{ h} \\ \text{Cookers/year} &= 400/15 = 26.67, \quad t_{\text{install}} = 1.5 \text{ h} \end{aligned}$$

Install hours/year $= 30.77 \cdot 1.0 + 40 \cdot 1.5 + 26.67 \cdot 1.5 = 130.77 \Rightarrow H_{\text{install}} = 130.77/52 = \mathbf{2.52}$ h/wk.

Step B — Field repairs (major and small)

Annual repair rates (conservative, labor-raising): majors = 10% of installed base; small electrics = 5%. Typical field MTTR window 1–2 h for majors, ∼0.5–0.75 h for smalls (we cap high to be conservative)[6].

Majors installed $= 3 \times 400 = 1{,}200$ units ⇒ 120 repairs/year. Smalls installed $= 3 \times 400 = 1{,}200$ units ⇒ 60 repairs/year.

[1] OECD, *Family size and household composition*, 2025. [(122)]
[2] EU Ecodesign Reg. (EU) 2019/2023 for washing machines; Commission guidance page. [(123), (124)]
[3] NAHB "Life Expectancy of Home Components": refrigerators ∼13 y; washers ∼10 y; gas ranges ∼15 y. [(125)]
[4] EEA product-lifespan monitoring for small appliances; microwaves ∼9.8 y; vacuum ∼10 y; coffee machines ∼5.5–6.5 y. [(126), (127)]
[5] Furniture longevity and circular-economy review. [(128), (129)]
[6] Failure modes and serviceability for appliances [(130)]; EU "right to repair" strengthens repair availability [(131)].

$$H_{\text{repair,maj}} = \frac{120 \times \{1.5,\ 1.2,\ 1.0\}}{52} = \{\mathbf{3.46},\ \mathbf{2.77},\ \mathbf{2.31}\}$$

$$H_{\text{repair,small}} = \frac{60 \times \{0.75,\ 0.60,\ 0.50\}}{52} = \{\mathbf{0.87},\ \mathbf{0.69},\ \mathbf{0.58}\}$$

Step C — Bench refurbishment

Share of replaced majors refurbished and redeployed: {10%, 25%, 40%} at {2.0, 1.5, 1.5} h/unit (modular parts at higher automation). Replaced majors/year = $30.77 + 40 + 26.67 = 97.44$.

$$H_{\text{refurb}} = \frac{97.44 \times \{0.10 \cdot 2.0,\ 0.25 \cdot 1.5,\ 0.40 \cdot 1.5\}}{52} = \{\mathbf{0.37},\ \mathbf{0.70},\ \mathbf{1.12}\}$$

Step D — Furniture assembly/repair allowance

Annualized minor assembly and repairs: 2.0 h/household/10 y = 0.2 h/y plus 1.0 h/y for 10% of households.

$$H_{\text{furn}} = \frac{(0.2 \times 400) + (0.1 \times 400 \times 1.0)}{52} = \frac{80 + 40}{52} = \mathbf{2.31}\ \text{h/wk.}$$

Step E — Scheduling/QA overhead

Apply overhead factor on (A–D) to cover dispatch, parts handling, documentation: {+30%, +20%, +15%}.

Summary (weekly hours per 1,000)

Table 10.1: Household goods & appliances: conservative weekly hours per 1,000 residents.

Scenario	Install	Major repair	Small repair	Refurb	Furniture	**Total**
Low automation	2.52	3.46	0.87	0.37	2.31	**11.7**
Medium automation	2.52	2.77	0.69	0.70	2.31	**10.3**
High automation	2.52	2.31	0.58	1.12	2.31	**9.8**

Note. Totals include scheduling/QA overhead of $\{30\%, 20\%, 15\%\}$ applied to the sum of Install + Major repair + Small repair + Refurb; Furniture is added afterward.

11 Production Equipment, Robotics, and Maintenance, Repair, and Operations

11.1 Scope, Floors, Boundary

Service floors. Asset availability consistent with sector targets (e.g., food, housing, logistics). Use ISO 55000 asset-management principles, TPM/OEE for effectiveness, and RCM for maintenance planning.[1]

Boundary. Local/direct labor for: (i) assembly of production equipment (final build/retrofit locally), (ii) installation & commissioning, (iii) preventive/predictive/corrective maintenance (MRO), (iv) spares/CMMS/inventory handling. Upstream component manufacturing hours are accounted elsewhere to avoid double counting.

Calculation log (per 1,000 residents)

A) Robotics & automation fleet

We model a cross-sector robot/automation pack (kitchen lines, warehouses, light manufacturing cells, utilities). Choose a conservative fleet size to *over*-count hours.[2]

Robots per 1,000 residents (planning default):

$$R \in \{10,\ 25,\ 50\} \quad \text{(low, medium, high automation).}$$

A1 — Preventive maintenance hours. OEM/field guidance: annual PM every 3,850–11,520 run-hours, with service visits typically $\sim 2-4$ labor-hours per robot-year plus daily/quarterly checks.[3] We adopt conservative PM hours/robot-year:

$$h_{\text{PM/robot}} \in \{4,\ 3,\ 2\} \text{ (low, med, high).}$$

Weekly PM hours:

$$H_{\text{PM, robots}} = \frac{R \cdot h_{\text{PM/robot}}}{52}.$$

A2 — Reactive & condition-based maintenance adders. SMRP benchmarks target 80/20 to 90/10 proactive/reactive.[4] We add reactive/CbM overhead on PM hours:

$$\alpha_{\text{react}} \in \{+20\%,\ +10\%,\ +5\%\}.$$

$$H_{\text{MRO, robots}} = H_{\text{PM, robots}}\,(1 + \alpha_{\text{react}}).$$

[1] Overview of ISO 55000 asset-management standards [(132), (133)]. TPM/OEE canon from Nakajima [(134)] and standard summaries [(135), (136)]. RCM reference guide [(137)]. Maintenance terminology per EN 13306 [(138)].

[2] IFR reports 4.28 M industrial robots in operation and average densities of 162 per 10,000 manufacturing employees, rising fast [(139), (140), (141)]. We convert to a *population-based* planning fleet by design choice, not by employment, to keep hours conservative.

[3] Examples: FANUC/ABB service intervals and schedules [**MotionCtrl-PM**, (142), (143), (144), (145), (146)]. Service time per PM often billed at ∼2–4 h/robot [(142)]. Typical robot life 80,000–100,000 h with annual PM [(147)].

[4] SMRP best-practice ratios summarized in industry guides [**Brightly-SMRP**, **SMRP-Workshop**].

A3 — Commissioning & installation (annualized). Typical robot cell commissioning requires multi-day integration; per-robot direct technician time often tens of hours, varying by end-effector and safety.[5] Assume install-time per new robot $t_{\text{inst}} \in \{40, 30, 24\}$ hours; life $L = 10$ years. Annualized weekly hours:

$$H_{\text{inst, robots}} = \frac{R \cdot (t_{\text{inst}}/L)}{52}.$$

B) Non-robot assets MRO (conveyors, ovens, pumps, HVAC, drives)

Industry-normalized budgeting uses maintenance cost as % of Replacement Asset Value (%RAV). Benchmarks: $\sim 2-5\%$ total maintenance cost per year.[6] Let:

$$\text{RAV}_{10} = \text{maintained replacement asset value per 1,000 residents in units of £10 million.}$$

Let β be total maintenance cost as %RAV (conservative $\beta \in \{5\%, 3.5\%, 2.5\%\}$). Let labor share of maintenance cost $s_L \in \{60\%, 50\%, 40\%\}$. With blended labor cost c_h €/h, annual labor hours:

$$\text{Hours}_{\text{year}} = \frac{\beta \cdot (10\,\text{M€}) \cdot \text{RAV}_{10} \cdot s_L}{c_h}.$$

Weekly:

$$H_{\text{MRO, nonrobot}} = \frac{\beta \cdot (10\,\text{M€}) \cdot \text{RAV}_{10} \cdot s_L}{52\, c_h}.$$

Planner note. Use a conservative c_h that *lowers* hours only if you have binding evidence; otherwise pick a modest loaded rate (e.g., 50 €/h) to avoid understating hours.[7]

C) Spares & CMMS overhead

Inventory control, kitting, receiving, data, QA. Apply an overhead on maintenance labor hours to cover spares/CMMS handling:[8]

$$\phi_{\text{spares}} \in \{+25\%,\ +20\%,\ +15\%\}.$$

$$H_{\text{spares}} = \phi_{\text{spares}} \cdot (H_{\text{MRO, robots}} + H_{\text{MRO, nonrobot}})\,.$$

D) Total

$$H_{\text{total}} = H_{\text{inst, robots}} + H_{\text{MRO, robots}} + H_{\text{MRO, nonrobot}} + H_{\text{spares}}.$$

Worked numbers (per 1,000 residents, with $\text{RAV}_{10} = 1.0$ and $c_h = 50\,£/\text{h}$)

Robotics block.

Low: $R{=}10,\ h_{\text{PM/robot}}{=}4\ \Rightarrow H_{\text{PM, robots}} = 0.77$ h/wk; $\alpha{=}20\% \Rightarrow H_{\text{MRO, robots}} = 0.92$

$t_{\text{inst}}{=}40\ \Rightarrow H_{\text{inst, robots}} = 0.77$

Med: $R{=}25,\ h_{\text{PM/robot}}{=}3 \Rightarrow H_{\text{MRO, robots}} = 1.62$ h/wk; $H_{\text{inst, robots}} = 1.44$

High: $R{=}50,\ h_{\text{PM/robot}}{=}2 \Rightarrow H_{\text{MRO, robots}} = 2.02$ h/wk; $H_{\text{inst, robots}} = 2.31$

[5] Integrator guidance: commissioning 2–5 days at cell-level [(148)]. Bespoke automation projects run months, but installation labor per robot is often $\mathcal{O}(16-40)$ hours; we annualize at the robot level [(149)].
[6] See SMRP materials and practitioner sources on %RAV [(150), (151), (152), (153)]. Cautionary note: MC/RAV is a guide, not a universal KPI [(154)].
[7] We parameterize c_h to be transparent and portable across wage contexts.
[8] SMRP inventory KPIs and maintenance-inventory guidance [(155)].

Non-robot MRO.

$$\text{Low: } \beta{=}5\%,\ s_L{=}60\% \Rightarrow H_{\text{MRO, nonrobot}} = \tfrac{0.05\cdot 10\text{M}\cdot 0.60}{52\cdot 50} = \mathbf{115.4}\ \text{h/wk}$$
$$\text{Med: } \beta{=}3.5\%,\ s_L{=}50\% \Rightarrow \mathbf{67.3}\ \text{h/wk} \quad \text{High: } \beta{=}2.5\%,\ s_L{=}40\% \Rightarrow \mathbf{38.5}\ \text{h/wk}$$

Spares/CMMS overhead.

$$\text{Low: } \phi{=}25\% \quad \text{Med: } 20\% \quad \text{High: } 15\%.$$

Summary (weekly hours per 1,000; $\text{RAV}_{10} = 1.0$, $c_h = 50\,£/\text{h}$)

Table 11.1: Production equipment & MRO labor. Conservative ranges with explicit parameters.

Scenario	Install (robots)	MRO (robots)	MRO (non-robots)	Spares/CMMS	**Total**
Low automation	0.77	0.92	115.4	29.8	**146.9**
Medium automation	1.44	1.62	67.3	14.1	**84.5**
High automation	2.31	2.02	38.5	6.1	**48.9**

Notes. Totals scale linearly with RAV_{10} and inversely with c_h.

12 Materials, Mining & Circular Flows

12.1 Scope, Floors, Exclusions

Service floors. Material quotas set by conservative, widely cited per-capita anchors (annual) converted to weekly per 1,000:

$$\begin{aligned}
\text{Steel} &= \tfrac{219}{52}\ \text{t/wk} \approx 4.21, && \text{global apparent use. [(156)]}\\
\text{Cement} &= \tfrac{376}{52}\ \text{t/wk} \approx 7.23, && \text{EU27 2021 anchor. [(157)]}\\
\text{Glass} &= \tfrac{21}{52}\ \text{t/wk} \approx 0.404, && \text{all glass types. [(158)]}\\
\text{Wood} &= \tfrac{0.5\times 1{,}000}{52}\ \text{m}^3\text{/wk} \approx 9.62, && \text{roundwood baseline. [(159)]}\\
\text{Organics} &= \tfrac{100}{52}\ \text{t/wk} \approx 1.92. && \text{EU biowaste floor. [(160)]}
\end{aligned}$$

Exclusions. Coal batch-heat, illegal logging, primary Al for non-essentials, and routine air freight. When clean routes raise labor, we accept the higher hours.

Boundary. *Plant operations* labor for steel/cement/glass/wood; plus circular flows: collection, MRF processing, and remanufacturing (or organics processing). Upstream mining & raw-material process hours are tracked separately when assembling national roll-ups.

12.2 Coefficients (conservative)

All values are *plant labor only* unless noted; where sources differ, we choose the higher labor figure.

Steel (h/t). U.S. average ∼1.9; frontier mini-mill ∼0.3. Use {4.0, 1.9, 1.0} for {low, med, high}. [(161), (162)]

Cement (h/t). EPA/IEA place plant labor at a few tenths of an hour per ton. Use {0.50, 0.40, 0.20}. [(163), (164)]

Glass (h/t). Modern float/container lines are highly automated. Use {2.0, 1.0, 0.6} (virgin). Circular glass manufacturing intensity handled below. [(158)]

Wood (h/m^3). Harvesting 0.12–4.15 h/m^3 by method; small sawmilling ∼1.2–1.6 h/m^3. Bundle as {3.0, 1.0, 0.5}. [(165), (166), (167)]

Circular flows (jobs per 1,000 t → h/t). Collection 1.23⇒2.46 h/t; MRF 2.00⇒4.00 h/t; recycled-input manufacturing: ferrous 4.12⇒8.24 h/t; glass 7.85⇒15.7 h/t; wood 2.80⇒5.6 h/t; organics processing 0.5⇒1.0 h/t. Job-year =2,000 h. [(168)]

Circular-content shares (policy defaults; higher labor accepted):
Low: steel 30%, glass 30%, wood reman 10%; Medium: 50%/60%/20%; High: 70%/80%/30%.

Calculation log (per 1,000 residents per week)

Steel.

$$H_s = T_s[(1-\rho_s)\,h_{s,\text{virgin}} + \rho_s\,(h_{s,\text{rec.mfg}} + h_{\text{collect}} + h_{\text{MRF}})]\,,\ T_s = 4.21.$$

Cement.

$$H_\mathrm{c} = T_\mathrm{c}\, h_\mathrm{c}, \quad T_\mathrm{c} = 7.23.$$

Glass.

$$H_\mathrm{g} = T_\mathrm{g}[(1-\rho_\mathrm{g})\, h_{\mathrm{g,virgin}} + \rho_\mathrm{g}\,(h_{\mathrm{g,rec.mfg}} + h_{\mathrm{collect}} + h_{\mathrm{MRF}})]\,,\ T_\mathrm{g} = 0.404.$$

Wood.

$$H_\mathrm{w} = V_\mathrm{w}[(1-\rho_\mathrm{w})\, h_{\mathrm{w,virgin}} + \rho_\mathrm{w}\, h_{\mathrm{w,reman}}]\,,\ V_\mathrm{w} = 9.62, \quad h_{\mathrm{w,reman}} = 2.8\ \mathrm{h/m^3}.$$

Note. We conservatively exclude a separate MRF term for wood when flows are direct take-back/deconstruction; add +2.46 h/t if curbside collection is used. [(168)]

Organics.

$$H_\mathrm{o} = T_\mathrm{o}\,(h_{\mathrm{collect}} + h_{\mathrm{org.proc}}), \quad T_\mathrm{o} = 1.92,\ h_{\mathrm{org.proc}} = 1.0.$$

Numerical results (rounded)

Low: $\rho_{\mathrm{s,g,w}} = (0.30, 0.30, 0.10) \Rightarrow H_\mathrm{s} \approx 30.4,\ H_\mathrm{c} \approx 3.6,\ H_\mathrm{g} \approx 3.3,\ H_\mathrm{w} \approx 21.2,\ H_\mathrm{o} \approx 6.7,$ Total $\approx \mathbf{65.1}$ h/wk/1,000.

Medium: $(0.50, 0.60, 0.20) \Rightarrow H_\mathrm{s} \approx 35.0,\ H_\mathrm{c} \approx 2.9,\ H_\mathrm{g} \approx 5.5,\ H_\mathrm{w} \approx 11.6,\ H_\mathrm{o} \approx 6.7,$ Total $\approx \mathbf{61.6}$.

High: $(0.70, 0.80, 0.30) \Rightarrow H_\mathrm{s} \approx 44.6,\ H_\mathrm{c} \approx 1.4,\ H_\mathrm{g} \approx 7.2,\ H_\mathrm{w} \approx 13.6,\ H_\mathrm{o} \approx 6.7,$ Total $\approx \mathbf{73.6}$.

Interpretation. Virgin-route plant hours fall with automation; higher circular content raises labor (accepted to cut emissions). Totals remain modest relative to food, care, or housing operations.

Summary (weekly hours per 1,000)

Table 12.1: Materials & circular flows: weekly labor hours per 1,000 residents.

Scenario	Steel	Cement	Glass	Wood	Organics	Total
Low automation, low circularity	30.4	3.6	3.3	21.2	6.7	**65.1**
Medium automation, mid circularity	35.0	2.9	5.5	11.6	6.7	**61.6**
High automation, high circularity	44.6	1.4	7.2	13.6	6.7	**73.6**

13 Energy System Buildout

13.1 Scope and boundary

Service floor. 2,000 kWh/person/year, all-electric baseline.[1]

Illustrative mix. 50% PV / 50% onshore wind.

Storage. 4-hour Li-ion sized to *average* load (conservative, one cycle/day); long-duration handled elsewhere.[2]

Grid retrofit. Distribution + transmission reinforcement proportional to added VRE capacity.

Counting rule. Construction & commissioning labor (CIM) only; manufacturing job-hours not counted here. Conversion from job-years uses 2,000 hours/job-year and annualization over a build horizon Y (here $Y = 10$).[3]

Calculation log (per 1,000 residents)

Inputs

$$E_{\text{year}} = 1{,}000 \times 2{,}000 = 2{,}000{,}000 \text{ kWh/yr} = 2.0 \text{ GWh/yr}, \qquad P_{\text{avg}} = \frac{E_{\text{year}}}{8{,}760} \approx 228.3 \text{ kW}.$$

Split energy equally: $E_{\text{PV}} = E_{\text{W}} = 1.0$ GWh/yr.

Sizing with conservative CFs

$$C_{\text{PV}} = \frac{E_{\text{PV}}}{\text{CF}_{\text{PV}} \cdot 8{,}760} = \frac{1{,}000 \text{ MWh}}{0.20 \cdot 8{,}760} \approx 0.571 \text{ MW},$$
$$C_{\text{W}} = \frac{E_{\text{W}}}{\text{CF}_{\text{W}} \cdot 8{,}760} = \frac{1{,}000}{0.35 \cdot 8{,}760} \approx 0.326 \text{ MW}.$$

Storage sized to 4 h of average load:

$$E_{\text{Sto}} = 4 \times P_{\text{avg}} \approx 0.913 \text{ MWh}, \qquad P_{\text{Sto}} = \frac{E_{\text{Sto}}}{4} \approx 0.228 \text{ MW}.$$

Employment factors and annualization

Construction/installation job-year factors (jy):

$$\begin{aligned}
&\text{PV:} \quad f_{\text{PV}} \in \{4.0,\ 2.5,\ 1.8\} \ \text{ jy/MW (low, med, high)}\\
&\text{Wind:} \ f_{\text{W}} \in \{4.0,\ 2.0,\ 1.2\} \ \text{ jy/MW}\\
&\text{Storage:} \ f_{\text{Sto}} \in \{0.60,\ 0.40,\ 0.25\} \ \text{ jy/MWh}
\end{aligned}$$

[1]Capacity-factor anchors: NREL ATB (utility-scale PV and land-based wind) and recent performance syntheses; PV CFs commonly 21–34% by resource class and wind CFs in the mid-30s. We adopt PV = 20% and wind = 35% to stay conservative [(169), (170), (171), (172)].

[2]Storage duty and ATB sizing/CF conventions; a 4 h device cycled once daily has a device CF of ∼ 16.7% [(173)].

[3]Method follows JEDI-style analyses and IRENA/ILO reviews that report construction job-years per MW (or per MWh for storage). We validate with NREL/JEDI documentation and EPA program guidance [(174), (175), (176), (177), (178)].

Ranges align with JEDI/NREL and industry syntheses (onshore wind ∼3–5 jy/MW; utility PV ∼2–4 jy/MW; storage reported per MWh/MW—parameterized here per MWh).[4] Annualized weekly hours for any technology "•":

$$H_\bullet = \frac{\text{Build Units}}{Y} \times f_\bullet \times \frac{2{,}000}{52}, \qquad Y = 10.$$

Grid reinforcement proxy (labor-based). Added line-km $\Delta\text{km} = k_{\text{km/MW}} \times (C_{\text{PV}} + C_{\text{W}})$ with $k_{\text{km/MW}} = 1.0$. Labor intensities: distribution $\ell_{\text{dist}} = 2{,}000$ h/km, transmission $\ell_{\text{tx}} = 3{,}500$ h/km, mix 70/30. Annualize over $Y = 10$.[5]

$$H_{\text{Grid}} = \frac{\Delta\text{km} \cdot (0.7\,\ell_{\text{dist}} + 0.3\,\ell_{\text{tx}})}{Y \cdot 52}.$$

Computed weekly hours (per 1,000)

Using the capacities above:

$$H_{\text{PV}} = \{8.8,\ 5.5,\ 4.0\}, \qquad H_{\text{W}} = \{5.0,\ 2.5,\ 1.5\},$$
$$H_{\text{Sto}} = \{2.1,\ 1.4,\ 0.9\}, \qquad H_{\text{Grid}} = 4.24 \ \ \text{(common across scenarios; conservative)}.$$

Summary (annualized build hours, per 1,000 residents)

Table 13.1: CAPEX build labor by component; weekly hours per 1,000. Horizon $Y = 10$ years.

Scenario	PV	Wind	Storage (4h)	Grid retrofit	**Total**
Low automation	8.8	5.0	2.1	4.2	**20.1**
Medium automation	5.5	2.5	1.4	4.2	**13.6**
High automation	4.0	1.5	0.9	4.2	**10.6**

Notes. PV/Wind entries include construction & commissioning only; manufacturing is counted in *Materials & Circular Flows.* The grid proxy bundles line and substation work; substitute detailed designs when available. Lower CFs or shorter horizons raise hours.

[4] See PV/wind CIM factors and syntheses [**Steinberg-2012-CIM**, (179), (180), (181), (182)]. Storage factors expressed per device energy are consistent with EPA and policy studies [(177), (183)].

[5] Proxy derived from utility/transmission estimating guides and JEDI Tx workups; replace with local design when available [**RSMeans-Guide-2025**, (184), (185), (186)].

14 Freight & Warehousing

Objective. Estimate *weekly human hours per 1,000 residents* to move non-food essentials via trunk modes (rail, inland waterway), ports, regional warehouses, and last-mile parcels plus white-glove deliveries. Heavy manufacturing hours are counted elsewhere. Road linehaul is omitted here (handled in the general logistics chapter); feeders to warehouses are included implicitly via warehouse touches.

14.1 Scope, Floors, Boundary

Scope. Global default. Unit = 1,000 residents.

Service floors. Baseline non-food goods flow sufficient for the essential basket (household goods, clothing, small durables). Parcel floor = 15 parcels/person/year.[1]

Boundary. Direct hours in trunk rail/barge operations (crew, yard, dispatch), port quayside/yard handling, warehouse receiving → putaway → pick/pack/ship, parcel rounds, and white-glove two-person deliveries. Upstream asset build and vehicle manufacturing are counted in the *Production Equipment, Robotics & MRO* chapter.

Calculation log (per 1,000 residents)

Inputs (conservative defaults)

- Annual non-food mass $M = 1.0$ t/person/year.[2]
- Weekly flow $T = \frac{1{,}000\,M}{52} = 19.23$ t/wk.
- Average domestic trunk distance $d = 300$ km (rail/barge split by scenario).[3]
- Containerized import share $\tau = 0.10$ TEU/person/year (expose to local stats).[4]
- Weekly TEU $= \frac{1{,}000\,\tau}{52} = 1.923$.

Labor coefficients (hours per unit)

Rail (per million ton-km). AAR productivity implies $\mathcal{O}(10^7 - 2 \times 10^7)$ ton-km per employee-year (2,000 h).[5]

$$h_{\text{rail}} \in \{0.30,\, 0.20,\, 0.10\} \text{ h per } 10^6 \text{ ton-km} \quad \text{(low, med, high).}$$

Barge (per million ton-km). Inland waterway labor intensity typically lower than rail.[6]

$$h_{\text{barge}} \in \{0.20,\, 0.15,\, 0.07\} \text{ h per } 10^6 \text{ ton-km.}$$

[1] Global parcel intensity near 7/person/year; leading markets ∼ 76–80. We set 15 as a conservative essentials floor [(93), (94)].

[2] Localize M with national commodity flow surveys or MRIO. We expose M parametrically to avoid overclaiming.

[3] Freight distance bands per BTS/Eurostat; 200–500 km is a common domestic linehaul range [(187), (188)].

[4] UNCTAD's *Review of Maritime Transport* compiles TEU/capita by country [(189)].

[5] AAR productivity series; ton-miles per employee converted to ton-km and hours/ton-km [(190)].

[6] USACE and CCNR market insights document large ton-km per crew; we keep a conservative band [(191), (192)].

Port handling (per TEU). Manual terminals $\sim$ 0.6–1.0 h/TEU; semi/fully automated $\sim$ 0.3–0.6 h/TEU.[7]

$$h_{\text{port}} \in \{0.80,\ 0.50,\ 0.30\} \text{ h/TEU.}$$

Warehousing (cases/hour; touch factor). Manual person-to-goods 70–100 cases/h with travel dominating pick time.[8] Use a *touch factor* $f_{\text{touch}} \in \{2.0,\ 1.6,\ 1.3\}$ (recv+put, pick, pack/ship), and base pick rate $r \in \{70,\ 100,\ 150\}$ cases/h.

Parcels (drops/hour). Vans 4–6/h; e-cargo bikes 7–10/h in dense cores; add fixed 10 h/wk hub handling.[9]

White-glove (large items). Two-person crew; deliveries per hour $\in \{0.6,\ 0.8,\ 1.0\}$ including placement/scheduling.[10]

Mode shares by scenario

Rail/barge share of trunk ton-km:

$$(\sigma_{\text{rail}}, \sigma_{\text{barge}}) = \begin{cases} (0.60,\ 0.40) & \text{low} \\ (0.70,\ 0.30) & \text{medium} \\ (0.80,\ 0.20) & \text{high} \end{cases} \quad \text{(assumes waterway access; if none, fold barge into rail).}$$

Compute

Trunk ton-km.

$$\text{tkm} = T \cdot d = 19.23 \times 300 = 5{,}769 \text{ ton-km/wk.}$$

Hours (rail + barge):

$$H_{\text{trunk}} = \frac{\text{tkm}}{10^6} \left(\sigma_{\text{rail}} h_{\text{rail}} + \sigma_{\text{barge}} h_{\text{barge}} \right).$$

Ports.

$$\text{TEU}_{\text{wk}} = 1.923, \qquad H_{\text{port}} = h_{\text{port}} \cdot \text{TEU}_{\text{wk}}.$$

Warehousing. Weekly cases with $m_{\text{case}} = 15$ kg:

$$\text{cases}_{\text{wk}} = \frac{T \cdot 1{,}000}{m_{\text{case}}} = \frac{19{,}230}{15} \approx 1{,}282.$$

Base pick hours = $\text{cases}_{\text{wk}}/r$. End-to-end:

$$H_{\text{wh}} = f_{\text{touch}} \cdot \frac{\text{cases}_{\text{wk}}}{r}.$$

Parcels. Parcels/wk $= \frac{15 \cdot 1{,}000}{52} \approx 288$.

$$H_{\text{parc}} = \frac{288}{\text{drops/h}} + 10 \quad \text{(hub).}$$

[7] UNCTAD RMT; automated-terminal case literature and performance benchmarking [(189), (193), (194)].
[8] *Warehouse & Distribution Science* on pick density; vendor data for manual vs. GTP zones [(9), (10)].
[9] Urban trials show higher productivity for cargo bikes; we keep conservative rates [(101), (102), (103)].
[10] Industry practice for furniture/appliance last-mile [(195), (196)].

White-glove. Assume $N_{\mathrm{LG}} = 5$ large-item deliveries/wk per 1,000 (conservative). Two-person crews:

$$H_{\mathrm{WG}} = N_{\mathrm{LG}} \times \frac{2}{\mathrm{deliv/h}}.$$

Summary (weekly hours per 1,000; rounded)

Table 14.1: Freight & warehousing labor (conservative defaults).

Scenario	Trunk (rail+barge)	Ports	Warehousing	Parcels	White-glove	**Total**
Low	0.0016	1.54	36.6	68	16.7	**122.8**
Medium	0.0011	0.96	20.5	58	12.5	**92.0**
High	0.0006	0.58	11.1	46	10.0	**67.7**

Parameters. Trunk shares low/med/high = (0.6/0.4, 0.7/0.3, 0.8/0.2); $h_{\mathrm{rail}} = (0.30, 0.20, 0.10)$, $h_{\mathrm{barge}} = (0.20, 0.15, 0.07)$ h per 10^6 t-km; $h_{\mathrm{port}} = (0.80, 0.50, 0.30)$ h/TEU; $r = (70, 100, 150)$ cph; $f_{\mathrm{touch}} = (2.0, 1.6, 1.3)$; parcel drops/h = $(5, 6, 8)$; white-glove deliv/h = $(0.6, 0.8, 1.0)$.

15 Care Services

Objective. Guarantee contact time for dependent care while minimizing non-contact hours. Contact time is a hard floor; automation trims only paperwork, scheduling, and travel.

15.1 Scope, Floors, Boundary

Service floors.

- *Early childhood education and care (ECEC)*: guaranteed places for 0–5 with ratios meeting OECD/EU quality guidance.[1] Baseline program length 30 h/week/child.
- *Elder home support*: weekly assistance for ADL/IADL consistent with WHO integrated care guidance.[2]
- *Disability support*: weekly personal assistance for people with significant functional limitations.[3]
- *Day centers*: staffed daytime programs for elders with supervision needs; conservative 1:5 participant-to-staff ratio.[4]

Boundary. Direct contact hours plus non-contact overhead (documentation, scheduling, supervision, training, travel). Clinical nursing and medical services sit in *Healthcare*. Institutional long-term care is covered there too.

Population anchors (per 1,000)

Age structure (global default, conservative labor-raising): 0–5 = 7%, 65+ = 18%.[5] Significant-disability prevalence for planning: 4% overall, assumed half overlaps with 65+ (counted in elder support), leaving **net 2%** across other ages.

$$\text{Children 0–5} = 70, \qquad \text{Elders 65+} = 180, \qquad \text{Net disability (non-elder)} = 20.$$

ECEC uptake (conservative): $0-2$ at 60%; $3-5$ at 90%.

Labor coefficients and conservative overheads

Contact ratios and hours.

- 0–2 ratio $= 1 : 3$; program 30 h/wk/child.[6]
- 3–5 ratio $= 1 : 8$; program 30 h/wk/child.[7]

[1] Staff–child ratio anchors: infants/toddlers often 1:3–1:4; preschool commonly 1:8–1:10. See OECD *Starting Strong* and the EU Quality Framework for ECEC [(197), (198)].
[2] WHO ICOPE emphasizes regular functional assessment and community support; we translate this to weekly home-support contact [(199)].
[3] WHO estimates ∼15% of people live with disability and ∼2–4% experience significant difficulties; we budget assistance for the significant-difficulty group [(200), (201)].
[4] Adult day services guidance commonly targets 1:6; we adopt 1:5 as a conservative floor [(202)].
[5] Rounded from UN World Population Prospects; use local structure when planning [(203)].
[6] Within OECD/EU quality bands [(197), (198)].
[7] Within OECD/EU quality bands [(197), (198)].

- Elder home support = 4 h contact/client/week.[8]
- Disability support (non-elder) = 4 h contact/client/week.[9]
- Day centers = 1:5 staff during program hours; 3 days/week, 6 h/day per attendee.[10]

Non-contact overhead multipliers on *contact* hours (documentation, scheduling, supervision, prep, travel):

$$\text{Low } +60\% \quad \text{Medium } +35\% \quad \text{High } +20\%,$$

reflecting evidence that travel/admin can consume large shares in home and day services; digital scheduling and e-records reduce this but do not touch contact time.[11] Add **+10% float** for coverage and training in all scenarios.

Calculation log (per 1,000 residents)

A) ECEC contact hours

Split 0–5 as 40% (0–2) and 60% (3–5).
0–2 attendees = $70 \times 0.40 \times 0.60 = 16.8$ children. Staff = $16.8/3 = 5.6$. Contact = $5.6 \times 30 = 168$ h/wk.
3–5 attendees = $70 \times 0.60 \times 0.90 = 37.8$ children. Staff = $37.8/8 = 4.725$. Contact = $4.725 \times 30 = 141.75$ h/wk.
ECEC contact total = $168 + 141.75 = \mathbf{309.75}$ h/wk.
Apply overheads and float:

$$H_{\text{ECEC}} = \begin{cases} 309.75 \times 1.60 \times 1.10 = \mathbf{545.2} & \text{low} \\ 309.75 \times 1.35 \times 1.10 = \mathbf{460.0} & \text{med} \\ 309.75 \times 1.20 \times 1.10 = \mathbf{408.9} & \text{high} \end{cases}$$

B) Elder home support

Clients = $0.25 \times 180 = 45$. Contact = $45 \times 4 = \mathbf{180}$ h/wk.
Overheads + float:

$$H_{\text{elder}} = \{180 \times 1.60 \times 1.10 = \mathbf{316.8}, \quad 180 \times 1.35 \times 1.10 = \mathbf{267.3}, \quad 180 \times 1.20 \times 1.10 = \mathbf{237.6}\}.$$

C) Day centers (elders)

Attendees = $0.10 \times 180 = 18$ persons. Participant-hours = $18 \times 3 \times 6 = 324$. Staff contact = $324/5 = \mathbf{64.8}$ h/wk.
Program overhead (coordination, records): $\{+20\%, +15\%, +10\%\}$:

$$H_{\text{day}} = \{64.8 \times 1.20 = \mathbf{77.8}, \quad 64.8 \times 1.15 = \mathbf{74.5}, \quad 64.8 \times 1.10 = \mathbf{71.3}\}.$$

[8] OECD LTC reporting and WHO guidance support multi-hour weekly home visits for ADL/IADL; we fix 4 h as a conservative floor [(204), (199)].
[9] Personal assistance norms vary; we set a conservative weekly floor [(201)].
[10] Conservative program length; ratio anchored to adult day services guidance [(202)].
[11] Home-care productivity studies and digital-government evidence find sizable non-contact shares; digital-by-default cuts paperwork and improves routing [(205), (206), (207)].

D) Disability support (non-elder)

Clients = 20. Contact = $20 \times 4 = \mathbf{80}$ h/wk.
Overheads + float:

$$H_{\text{disab}} = \{80 \times 1.60 \times 1.10 = \mathbf{140.8}, \quad 80 \times 1.35 \times 1.10 = \mathbf{118.8}, \quad 80 \times 1.20 \times 1.10 = \mathbf{105.6}\}.$$

E) Respite & case management

Respite pool = **11** h/wk (contact). Case management = 0.2 h/client/wk for elder+disability clients $(45 + 20) \times 0.2 = \mathbf{13}$ h/wk; add 10% admin = **14.3** h/wk.

Summary (weekly hours per 1,000; rounded)

Table 15.1: Care services labor with contact time protected.

Scenario	ECEC	Elder home	Day centers	Disability	Respite	Case mgmt	**Total**
Low automation	545	317	78	141	11	14	**1,106**
Medium automation	460	267	75	119	11	14	**946**
High automation	409	238	71	106	11	14	**849**

16 Public Space & Facilities

16.1 Scope, Floors, Boundary

Service floors.

- Parks access ≥ 20 m^2/person of public green (more than the 9 m^2/person minimum often cited).[1]
- Weekly mechanical street sweeping and sidewalk cleaning in built-up areas; sidewalks both sides, design width ≥ 2.0 m.[2]
- Public toilets open daily with multiple cleans/day.[3]
- Civic-interior cleaning to APPA Level 2 (orderly spotlessness); preventive maintenance at IFMA benchmark levels.[4]

Boundary. Direct local labor: sweeping, washing, litter pickup, horticulture, restroom cleaning/attending, custodial interior care, light PM, graffiti abatement, furniture upkeep. Heavy repairs and capital works are counted in Housing/Infrastructure.

Stock and planning defaults (per 1,000 residents)

- **Streets.** 5 km centerline. Curb-km = 2$\times$ centerline = 10.
- **Sidewalks.** Both sides, 2.0 m width $\Rightarrow$ area $A_{\text{sw}} = 5{,}000 \times 2 \times 2.0 = 20{,}000$ m^2/wk to be cleaned.
- **Parks.** 20 m^2/person $\Rightarrow$ 2.0 ha per 1,000.
- **Public toilets.** 0.5 units per 1,000 (1 per 2,000 residents), each with 3 cleans/day.
- **Civic interiors.** 1,000 m^2 of public interior (halls, small civic centers) per 1,000 (schools/clinics modeled elsewhere).

Labor coefficients (conservative)

Street sweeping. Mechanical sweeper productivity band: {30, 45, 60} curb-km per 8 h (low/med/high).[5]

Sidewalk cleaning. Machine-assisted wash/scrub: {400, 600, 1,000} m^2/h.[6]

Public toilets. Clean time 15 min/clean + weekly deep clean 1 h; add 1 h/day attendant time.[7]

Parks upkeep. Horticulture/litter/mowing staffing intensity: {10, 7, 5} h/ha/wk.[8]

Civic custodial. APPA Level 2 daily: productivity {1,000, 1,500, 2,000} m^2 per 8 h-shift.[9]

[1] WHO reviews cite 9 m^2/capita as a common minimum; we adopt 20 m^2 to be conservative [(208)].
[2] Typical urban sidewalk design guidance sets 1.8–2.4 m clear width; we set 2.0 m [(209)].
[3] Cleaning time anchors from ISSA cleaning-times compendium; multiple short cleans/day are standard [(210)].
[4] APPA custodial staffing levels and productivity bands [(211)]. IFMA O&M benchmarks for PM planning [(212)].
[5] Road-maintenance manuals and agency productivity guides report tens of curb-km per operator-shift; we keep a conservative band [(213), (214)].
[6] ISSA task-time tables for floorcare with auto-scrubbers/pressure units; we choose lower productivities for street conditions [(210)].
[7] ISSA restroom task times; public-toilet guidance recommends multiple short cleans/day [(210), (215)].
[8] NRPA agency performance shows acres/FTE medians; we invert to h/ha/wk and choose conservative hours [(216)].
[9] APPA custodial staffing guidelines [(211)].

Light PM (civic). Preventive-maintenance allowance 0.1 $\mathrm{h/m^2/y} \Rightarrow 0.002\ \mathrm{h/m^2/wk}$.[10]

Public-realm overhead. Litter/graffiti/furniture adders on street+sidewalk hours: $\{+30\%, +20\%, +15\%\}$. Fixed graffiti and furniture pools 2 h/wk each.[11]

Calculation log (weekly per 1,000)

A) Streets

Weekly sweep once:

$$H_{\text{str}} = \frac{\text{curb-km}}{\text{km per 8h}} \times 8 = \left\{\frac{10}{30}, \frac{10}{45}, \frac{10}{60}\right\} \times 8 = \{2.67,\ 1.78,\ 1.33\}\ \text{h}.$$

B) Sidewalks

$$H_{\text{sw}} = \frac{A_{\text{sw}}}{\text{rate}} = \left\{\frac{20{,}000}{400}, \frac{20{,}000}{600}, \frac{20{,}000}{1{,}000}\right\} = \{50.0,\ 33.3,\ 20.0\}\ \text{h}.$$

Public-realm overhead on (A)+(B): $\times\{1.30,\ 1.20,\ 1.15\}$.

C) Parks

$$H_{\text{park}} = \{10,\ 7,\ 5\}\ \text{h/ha/wk}\ \ \times 2.0\ \text{ha} = \{20,\ 14,\ 10\}\ \text{h}.$$

D) Public toilets

Per unit: cleans $= 3 \times 0.25$ h/day $\times 7 = 5.25$ h/wk; deep clean $= 1$ h/wk; attendant $= 7$ h/wk. Total $= 13.25$ h/wk/unit. With 0.5 units:

$$H_{\text{toil}} = 0.5 \times 13.25 = 6.63\ \text{h}.$$

E) Civic interiors

Custodial (5 days/week at APPA Level 2):

$$H_{\text{cust}} = 5 \times 8 \times \frac{A_{\text{civic}}}{\text{m}^2/\text{shift}} = \{40.0,\ 26.7,\ 20.0\}\ \text{h}, \qquad A_{\text{civic}} = 1{,}000\ \text{m}^2.$$

Light PM:

$$H_{\text{PM}} = A_{\text{civic}} \times 0.002 = 2.0\ \text{h}.$$

F) Fixed small pools

Graffiti = 2 h; street-furniture upkeep = 2 h.

[10] IFMA O&M benchmarks; small-systems PM allowance [(212)].

[11] Public-space management toolkits recommend explicit litter/graffiti allowances [(217), (213)].

Results (weekly hours per 1,000; rounded)

Table 16.1: Public space & facilities: conservative weekly hours per 1,000 residents.

Scenario	Streets+Sidewalks	Parks	Toilets	Custodial	PM	Graffiti	Furniture	**Total**
Low	68.5	20.0	6.6	40.0	2.0	2.0	2.0	**141.1**
Medium	42.1	14.0	6.6	26.7	2.0	2.0	2.0	**95.5**
High	24.5	10.0	6.6	20.0	2.0	2.0	2.0	**67.2**

Notes. Streets+Sidewalks include litter/graffiti/furniture overhead on cleaning time. Parks excludes major capital works. Civic area is a placeholder; scale linearly with your stock.

17 Culture, Libraries, Media & Knowledge Commons

17.1 Scope, Floors, Boundary

Access floors.

- **Public libraries.** At least **6 staffed open-hours/week per 1,000** (equivalent to a 60-hour branch per 10,000), plus digital access 24/7.[1]
- **Programs.** Library programs baseline **0.4 events/week/1,000** (20 attendees/event), consistent with PLS program-intensity ranges.[2]
- **Culture venues.** Community arts/culture space open **2 h/week/1,000** (e.g., 20 h/week per 10,000) with staffed access.
- **Public-interest media.** Minimum newsroom capacity equal to **0.08 reporters per 1,000** (80/million), plus production/editorial support.[3]
- **Knowledge commons.** Open repository + digital preservation capability following NDSA Levels; baseline staffing **1 FTE per 100,000** (shared) ⇒ 0.01 FTE/1,000.[4]

Boundary. Direct local labor: service-desk, programming, community outreach, newsroom reporting/production, repository operations and preservation. Building O&M sits in *Public Space & Facilities*.

Labor coefficients and conservative overheads

Libraries. Staffed open-hours: $H_{\text{open,lib}} = 6$ h/wk/1,000. Staffing intensity per open-hour $s_{\text{lib}} \in \{1.7, 1.5, 1.3\}$ person-hours (low/med/high). Non-contact overhead multiplier $\mu_{\text{lib}} \in \{1.40, 1.25, 1.15\}$ (records, selection, shelving, training). Programs: $p = 0.4$ events/week/1,000, $h_{\text{prog}} = 5$ h/event (delivery + prep + outreach). Digital helpdesk $\in \{1.5, 1.2, 1.0\}$ h/wk/1,000.[5]

Culture venues. Open-hours: $H_{\text{open,cult}} = 2$ h/wk/1,000; staffing $s_{\text{cult}} \in \{1.5, 1.3, 1.1\}$; non-contact $\mu_{\text{cult}} \in \{1.35, 1.20, 1.10\}$. Programs: 0.2 events/week/1,000; 6 h/event including artist/tech support; +15% setup overhead (all scenarios).

Public-interest media. Reporters $r = 0.08/1{,}000$. Reporter hours $= r \times 40$=3.2 h/wk/1,000. Production/editorial overhead factors $\phi \in \{+100\%, +75\%, +50\}$. Engineering/digital ops = 0.5 h/wk/1,000.[6]

[1] IFLA guidelines require hours aligned to community convenience and 24/7 web access where feasible [(218)]. U.S. Public Libraries Survey (PLS) defines "public service hours" and is the basis for open-hour benchmarking [(219), (220)].

[2] IMLS FY2019 shows program attendance from ∼237 to 751 per 1,000 residents annually; a 20-attendee event implies ∼0.2–0.7 programs/week/1,000. We set 0.4 as a conservative floor [(221), (222)].

[3] U.S. newsroom employment has contracted; ratios of ∼1 reporter per 14,250 population (70/million) are reported. We set 80/million as a floor [(223), (224)].

[4] NDSA Levels v2.0 define preservation tasks; OpenAIRE guidelines define repository interoperability. Floors imply stable staffing and governance [(225), (226), (227)].

[5] IFLA service guidance for hours; PLS/PLA for program intensity; library task-time practice for prep/outreach [(218), (221), (222)].

[6] Population-to-reporter anchors from newsroom employment analyses; floor set to exceed current U.S. average to restore

Repositories. Staffing $\in \{1.2, 1.0, 0.8\}$ h/wk/1,000 to meet OpenAIRE/NDSA practices (operations, metadata, fixity, storage checks).[7]

Calculation log (per 1,000 residents)

A) Libraries

Desk hours $= H_{\text{open,lib}} \times s_{\text{lib}} = \{10.2,\ 9.0,\ 7.8\}$. Apply overhead $\mu_{\text{lib}} \Rightarrow \{14.28,\ 11.25,\ 8.97\}$.
Programs $= p \times h_{\text{prog}} = 0.4 \times 5 = 2.0$. Digital $= \{1.5,\ 1.2,\ 1.0\}$.
$\Rightarrow H_{\text{lib}} = \{14.28 + 2 + 1.5,\ 11.25 + 2 + 1.2,\ 8.97 + 2 + 1.0\} = \{\mathbf{17.8},\ \mathbf{14.5},\ \mathbf{12.0}\}$.

B) Culture venues

Open staffing $= H_{\text{open,cult}} \times s_{\text{cult}} = \{3.0,\ 2.6,\ 2.2\}$. Apply $\mu_{\text{cult}} \Rightarrow \{4.05,\ 3.12,\ 2.42\}$.
Programs $= 0.2 \times 6 = 1.2$ with $+15\%$ setup $= 1.38$.
$\Rightarrow H_{\text{cult}} = \{\mathbf{5.4},\ \mathbf{4.5},\ \mathbf{3.8}\}$.

C) Public-interest media

Reporter hours $= 3.2$. Apply $\phi \Rightarrow \{6.4,\ 5.6,\ 4.8\}$. Add engineering $+0.5$.
$\Rightarrow H_{\text{media}} = \{\mathbf{6.9},\ \mathbf{6.1},\ \mathbf{5.3}\}$.

D) Repositories & preservation

$\Rightarrow H_{\text{repo}} = \{\mathbf{1.2},\ \mathbf{1.0},\ \mathbf{0.8}\}$.

Results (weekly hours per 1,000; rounded)

Table 17.1: Culture, libraries, media & knowledge commons: conservative weekly hours per 1,000 residents.

Scenario	Libraries	Culture venues	Public media	Repositories	**Total**
Low automation	17.8	5.4	6.9	1.2	**31.3**
Medium automation	14.5	4.5	6.1	1.0	**26.1**
High automation	12.0	3.8	5.3	0.8	**21.9**

Notes. Open-hours floors scale with population (e.g., 60 h/week per 10,000). Program intensity aligns with PLS ranges. Media floor restores local coverage above current averages. Repository staffing meets OpenAIRE/NDSA practice.

local coverage [(223), (224)].

[7] Repository staffing literature and guidelines emphasize sustained FTEs; we parameterize per population for municipal-scale commons [(226), (228), (229), (230), (231)].

18 Environment, Biodiversity & Restoration

18.1 Scope, Floors, Boundary

Access & area floors.

- **Re/afforestation:** plant and establish **2.0 ha/year** of native forest per 1,000.[1]
- **Wetlands:** restore **0.20 ha/year** of marsh/riparian per 1,000 with native plugs/seed and hydrology fix.[2]
- **Urban canopy:** plant **20 street/park trees/year** per 1,000; prune public stock on a **5–6 yr cycle**. Water new trees weekly for 3 years.[3]
- **Biodiversity monitoring:** track restored hectares every season (birds/veg) with standard protocols; allow UAV assists where valid.[4]

Boundary. Direct field labor: site prep, planting, early tending, invasive control, watering, pruning, transects/point counts, and data checks.

Program stock (per 1,000 residents, steady pipeline)

- Forest restoration planted each year: $A_{\text{for}} = 2.0$ ha. Early-tending pool at steady state = 2 prior cohorts = 4.0 ha under tending.
- Wetlands planted each year: $A_{\text{wet}} = 0.20$ ha. Early-tending pool = 0.40 ha.
- Urban trees: new $N_{\text{new}} = 20$ trees/yr; establishment pool $= 3 \cdot N_{\text{new}} = 60$ trees watered weekly; public stock baseline $N_{\text{stock}} = 160$ trees/1,000 (conservative vs. city ratios).[5]

Labor coefficients (conservative bands)

Re/afforestation. Initial site-prep+planting hours per ha:

$$h_{\text{for,init}} \in \{760,\ 120,\ 60\}\ \text{h/ha} \quad \text{(low, med, high)},$$

[1] Early-site work and planting man-days per ha are large when manual; FAO indicates 20–40 md/ha for clearing *plus* 5–15 md/ha planting *plus* 20–40 md/ha nursery/transport, i.e., 45–95 md/ha (8 h/md) [(232)]. Mechanized planters raise throughput by orders of magnitude [(233), (234)].

[2] Wetland installation uses dense plugs or seed; planting rates ∼200–800 plugs/person-day depending on conditions [(235)]. Spacing guidance and plug methods in NRCS/BWSR notes [(236), (237), (238)].

[3] Public guidance: weekly 15 gal/tree for three years [(239)]. Cities run 3–6 yr pruning cycles [(240), (241)]. Poor maintenance raises downstream costs and risks [(242)].

[4] Point-count standards [(243), (244)]; vegetation and transect methods [(245)]. UAV-assisted surveys can reduce field time in open habitats [(246)].

[5] Example ratio: Cambridge, MA manages ∼19,000 public trees for ∼118,000 people (∼161/1,000) on a 6-year cycle [(241)].

anchored to FAO manual man-day ranges at the high end and mechanized planters at the low end.[6] Early tending (weed control/beating-up) per ha-year (years 1–2 only):

$$h_{\text{for,tend}} \in \{40,\ 30,\ 20\}\ \text{h/ha/yr},$$

consistent with "clean-weeded" emphasis in years 1–2.[7]

Wetlands. Initial planting+light grading per ha:

$$h_{\text{wet,init}} \in \{300,\ 150,\ 100\}\ \text{h/ha},$$

compatible with plug densities and crew rates.[8] Early tending/invasives per ha-year (years 1–2):

$$h_{\text{wet,tend}} \in \{30,\ 20,\ 15\}\ \text{h/ha/yr}.$$

Urban canopy. Per-tree activities:

$$\begin{aligned}
&\text{Planting hours/tree} \in \{1.5,\, 1.0,\, 0.8\},\\
&\text{Watering event} \in \{0.15,\, 0.15,\, 0.10\}\ \text{h/tree/week for 3 yrs},\\
&\text{Prune hours/tree/event} \in \{0.50,\, 0.40,\, 0.30\},\ \text{cycle } = \{5, 6, 6\}\ \text{yrs}.
\end{aligned}$$

Water guidance per week for three years from city standards; cycle pruning evidenced in practice.[9]

Biodiversity monitoring. Per restored ha-year:

$$h_{\text{mon}} \in \{4.0,\ 2.0,\ 0.5\}\ \text{h/ha/yr},$$

mixing point counts, veg transects, and UAV assists where valid.[10]

Program float. Add +10% to cover training, supervision, and QA.

Calculation log (weekly h per 1,000)

A) Forest restoration

Initial (annualized): $H_{\text{for,init}} = \dfrac{A_{\text{for}} \cdot h_{\text{for,init}}}{52}$. Early tending pool (steady): $H_{\text{for,tend}} = \dfrac{(2 \cdot A_{\text{for}}) \cdot h_{\text{for,tend}}}{52}$. Numerical (low/med/high):

$$\begin{aligned}
H_{\text{for,init}} &= \{29.2,\, 4.6,\, 2.3\}, \quad H_{\text{for,tend}} = \{3.1,\, 2.3,\, 1.5\},\\
H_{\text{forest}} &= \{32.3,\, 6.9,\, 3.9\}.
\end{aligned}$$

B) Wetlands

Initial (annualized): $H_{\text{wet,init}} = \dfrac{A_{\text{wet}} \cdot h_{\text{wet,init}}}{52}$. Early tending: $H_{\text{wet,tend}} = \dfrac{(2 \cdot A_{\text{wet}}) \cdot h_{\text{wet,tend}}}{52}$. Numerical:

$$H_{\text{wet}} = \{1.38,\, 0.73,\, 0.50\}.$$

[6] FAO 45–95 md/ha ⇒ 360–760 h/ha; we use the top of that range for *low*. Mechanical planters: 4,000–6,000 seedlings/crew-day [(233)]; even at 1,100 stems/ha this implies single-digit *planting* hours/ha; we retain extra hours for site prep/logistics [(234), (247)].

[7] Silviculture guidance: keep plantations weed-free in years 1–2; frequent weeding and beating-up [(248), (249), (250)].

[8] Plug spacing often 0.5–1.5 m; 200–800 plugs/person-day depending on conditions [(235), (236), (237)].

[9] Water weekly 15 gal for 3 years [(239)]; 3–6 yr pruning cycles [(240), (241)].

[10] Bird point-count standards (10-min counts, repeated visits) [(243), (244)]; vegetation transects per BLM manual [(245)]; UAV time in open habitats can be ∼0.2 h/ha for image capture [(246)].

C) Urban canopy

Planting (annualized): $H_{\text{plant}} = \dfrac{N_{\text{new}} \cdot \text{hrs/tree}}{52} = \{0.58,\ 0.38,\ 0.31\}$.
Watering: $H_{\text{water}} = (3N_{\text{new}}) \cdot \text{h/event} = \{9.0,\ 9.0,\ 6.0\}$ h/wk.
Pruning (annualized): $H_{\text{prune}} = \dfrac{N_{\text{stock}}}{\text{cycle}} \cdot \text{hrs/tree/52} = \{0.31,\ 0.21,\ 0.15\}$.
Total $H_{\text{canopy}} = \{9.89,\ 9.59,\ 6.46\}$.

D) Biodiversity monitoring

Restored hectares per year monitored: $A_{\text{for}} + A_{\text{wet}} = 2.2$ ha.
$H_{\text{mon}} = \dfrac{(2.2) \cdot h_{\text{mon}}}{52} = \{0.17,\ 0.085,\ 0.021\}$.

E) Add float

Apply +10% to subtotal.

Results (weekly hours per 1,000; rounded)

Table 18.1: Environment & restoration: conservative weekly hours per 1,000 residents.

Scenario	Forest	Wetlands	Urban canopy	Monitoring	**Total**
Low	32.3	1.38	9.89	0.17	**48.1**
Medium	6.9	0.73	9.59	0.09	**19.0**
High	3.9	0.50	6.46	0.02	**12.0**

Notes. Urban watering dominates steady labor; mechanize routing and hydrant fills. Forest hours are front-loaded in initial cohorts; tending tapers after year 2. Totals include a +10% program float. If local targets exceed the floors, scale linearly.

19 Disaster Risk & Civil Protection

19.1 Scope, Floors, Boundary

Service floors.

- Fire: first-due engine travel $\leq 240\,\text{s}$ to 90% of incidents; initial crew ≥ 4 firefighters per engine and truck; effective response force sized per risk.[1]
- EMS: ALS ambulance response aligned with chain-of-survival targets; 24/7 coverage with two-person crew.[2]
- Dispatch/EOC: continuous call-taking/dispatch; incident command per NIMS/ICS.[3]
- Stockpiles: rotation and QA for essential supplies; surge logistics capability.[4]

Boundary. Direct human hours: fire companies (engine, truck), ALS ambulance crews, call-taking/dispatch, emergency operations center (EOC) readiness, fire prevention/inspection, and emergency stockpile logistics. Hospital care sits in *Healthcare*.

Staff ladders (per 1,000): apparatus-based sizing

We size by fractional apparatus coverage; population is a proxy for risk exposure under urban travel-time grids.

$$
\begin{array}{llll}
\text{Engine coverage density} & \epsilon_E = \dfrac{1}{20{,}000} \text{ engines per person} & \Rightarrow & \epsilon_E^{(1k)} = 0.05 \\
\text{Truck coverage density} & \epsilon_T = \dfrac{1}{60{,}000} \text{ trucks per person} & \Rightarrow & \epsilon_T^{(1k)} \approx 0.0167 \\
\text{Ambulance density} & \epsilon_A = \dfrac{1}{25{,}000} \text{ ALS units per person} & \Rightarrow & \epsilon_A^{(1k)} = 0.04
\end{array}
$$

Crew-hours per apparatus (24/7):

$$H_E = 4 \times 24 \times 7 = 672, \quad H_T = 4 \times 24 \times 7 = 672, \quad H_A = 2 \times 24 \times 7 = 336 \;\; \text{(h/week)}.$$

Weekly *operational* hours per 1,000:

$$H_{\text{ops}} = 672(\epsilon_E^{(1k)} + \epsilon_T^{(1k)}) + 336\,\epsilon_A^{(1k)}.$$

Numerical: $H_{\text{ops}} = 672(0.05 + 0.0167) + 336(0.04) = \mathbf{58.24}$ h/wk/1,000.

[1] NFPA 1710 sets response time and crew-size benchmarks for career fire departments; we adopt the travel-time and four-person company floors [**NFPA-1710-2020**].

[2] AHA resuscitation guidance frames 8–10 minute targets for defibrillation; system design uses 24/7 ALS units with two-person crews [**AHA-ALS-2020**, **WHO-EMS-2015**].

[3] NIMS/ICS defines activated roles and training; ECC staffing follows public-safety standards [**FEMA-NIMS-2017**, **NENA-Staff-2018**].

[4] Sphere standards and IFRC logistics guidance underpin minimums for warehousing, rotation, and QA [**Sphere-2018**, **IFRC-Logistics-2018**].

Readiness/overhead pools (per 1,000).

- Fire prevention/inspection: {0.6, 0.5, 0.4} h/wk (low/med/high).[5]
- ECC dispatch & EOC readiness: {2.0, 1.5, 1.0} h/wk.[6]
- Stockpile logistics (rotation, QA, cycle counts): {2.5, 1.8, 1.2} h/wk.[7]
- Training/exercise add-on on H_{ops}: {+15%, +10%, +8%}.[8]

Calculation log (weekly h per 1,000)

$$\begin{aligned} H_{\text{base}} &= H_{\text{ops}} + H_{\text{prev}} + H_{\text{ECC/EOC}} + H_{\text{stock}} \\ &= 58.24 + \{0.6, 0.5, 0.4\} + \{2.0, 1.5, 1.0\} + \{2.5, 1.8, 1.2\} \\ &= \{63.34,\ 62.04,\ 60.84\}. \end{aligned}$$

Add training:

$$H_{\text{total}} = H_{\text{base}} + \{0.15,\ 0.10,\ 0.08\} \times 58.24 = \{\mathbf{72.1},\ \mathbf{67.9},\ \mathbf{65.5}\}\ \text{h/wk/1,000}.$$

Summary (weekly hours per 1,000; rounded)

Table 19.1: Disaster risk & civil protection: conservative weekly hours per 1,000 residents.

Scenario	Engines+Trucks	Ambulances	Prevention	ECC/EOC	Stockpiles	**Total**
Low	44.8	13.4	0.6	2.0	2.5	**72.1**
Medium	44.8	13.4	0.5	1.5	1.8	**67.9**
High	44.8	13.4	0.4	1.0	1.2	**65.5**

Notes. Engines/trucks and ambulances are *operational hours* from fixed crews; they do not decline with admin automation. Apparatus densities reflect urban grids; rural/very-dense cores should be parameterized by travel-time coverage and incident load. Training add-on is explicit.

[5] NFPA fire prevention programs require routine occupancy checks; we assign a conservative per-1,000 pool [**USFA-Needs-2020**].

[6] ECC staffing per NENA guidance; EOC duty officer/rotation maintained at a small steady-state [**NENA-Staff-2018**, **FEMA-NIMS-2017**].

[7] Sphere/IFRC logistics recommend regular rotation and recordkeeping; we budget a conservative minimal weekly pool [**Sphere-2018**, **IFRC-Logistics-2018**].

[8] NIMS/ICS and professional standards require recurrent drills; we add a percentage of operational hours for training [**FEMA-NIMS-2017**, **NFPA-1710-2020**].

20 Administration & Justice

20.1 Scope, Floors, Boundary

Service floors.

- **Universal ID & vital events.** Birth, death, marriage, divorce registered; legal ID coverage $= 100\%$ with renewals on schedule.[1]
- **Courts.** Clearance $\geq 100\%$ annually; disposition time within CEPEJ/OECD benchmarks.[2]
- **Prosecution & legal aid.** Prosecutorial review for chargeable cases.[3]

Boundary. Direct public-facing and adjudicative hours: counters, back office, registrars, judges, clerks, prosecutors, duty solicitors/legal aid..

Inputs (per 1,000; conservative defaults)

Demography and civil events (annual rates per 1,000 people):

$$\text{Births } = 17, \text{ Deaths } = 8 \text{ (UN global bands).}^{4}$$

Marriages $= 5$, divorces $= 2$ per 1,000/y.[5]

ID/registry transactions (annual per 1,000):

$$\text{Nat. ID renewals } = 100 \text{ (10-year validity), Passports } = 60 \text{ (10-year validity).}^{6}$$

Address updates $= 100$; extract/certified copies $= 50$.[7]

Court inflow (annual per 1,000):

$$\text{Civil/administrative litigious } = 20, \quad \text{Criminal (chargeable)} = 15.$$

Anchors: CEPEJ inflow medians per 100 inhabitants imply $\mathcal{O}(20)$ civil and $\mathcal{O}(15)$ criminal per 1,000/y in many systems.[8]

Automation scenarios (processing minutes per transaction)

Low Counter-heavy, paper files, manual checks.

Medium EID + e-docs, e-filing for routine matters, basic straight-through processing.

[1] UN principles for CRVS and ID4D stress universal, timely, and continuous registration and ID coverage [(251), (252)].
[2] CEPEJ defines clearance rate and disposition time; we require CR $\geq 100\%$ [(253)].
[3] OECD access-to-justice guidance and legal needs surveys ground the baseline [(254), (255)].
[4] Crude birth and death rates from UN World Population Prospects; we adopt upper-mid bands for conservatism [(203)].
[5] UN Demographic Yearbook series reports marriage/divorce rates; we set conservative global floors [(256)].
[6] National ID coverage from ID4D; passport validity norms per ICAO Doc 9303 and major jurisdictions (10-year adults) [(252), (257)].
[7] Residential mobility near 8–12%/y in many countries; we adopt 10% updates per 1,000 to be conservative [(258)]. Copies are a planner parameter (set high to err on labor).
[8] See CEPEJ 2022 evaluation report, tables on incoming cases per 100 inhabitants [(253)].

High End-to-end digital, registers interoperate; straight-through by default, human review on exceptions.[9]

Calculation log (per 1,000 residents)

A) IDs & civil registration

Minutes of staff time per transaction (low/medium/high):

$$\text{Birth, death: } (60, 30, 15), \quad \text{Marriage: } (60, 30, 20), \quad \text{Divorce (registry step): } (90, 45, 30),$$
$$\text{Nat. ID: } (30, 15, 10), \ \text{Passport: } (40, 20, 12), \ \text{Address: } (15, 8, 5), \ \text{Extracts: } (10, 6, 4).$$

Weekly hours are annual transactions /52 times minutes /60, plus non-contact overhead for QA/supervision:

$$\mu_{\text{reg}} = \begin{cases} +20\% & \text{low} \\ +15\% & \text{medium} \\ +10\% & \text{high} \end{cases}$$

Numerical result: $H_{\text{registry}} = \{3.61,\ 1.77,\ 1.04\}$ h/wk/1,000.

B) Courts (judges+clerks system hours per resolved case)

Hours/case (low/med/high), sized from weighted-caseload literature:[10]

$$\text{Civil/admn} = (6, 4, 3) \text{ h}, \qquad \text{Criminal (non-serious)} = (4, 3, 2) \text{ h}.$$

With inflow above and clearance = 100%:

$$H_{\text{courts}} = \left\{ \tfrac{20}{52} \cdot 6 + \tfrac{15}{52} \cdot 4, \quad \tfrac{20}{52} \cdot 4 + \tfrac{15}{52} \cdot 3, \quad \tfrac{20}{52} \cdot 3 + \tfrac{15}{52} \cdot 2 \right\} = \{3.46,\ \mathbf{2.40},\ 1.73\}.$$

C) Prosecution

Hours per criminal case $(3, 2, 1.5)$.[11]

$$H_{\text{pros}} = \left(\tfrac{15}{52}\right) \cdot (3, 2, 1.5) = \{0.87,\ 0.58,\ 0.43\}.$$

D) Legal aid

Matters = 50/1,000/y; hours/matter $(3, 2, 1.5)$.[12]

$$H_{\text{aid}} = \left(\tfrac{50}{52}\right) \cdot (3, 2, 1.5) = \{2.88,\ 1.92,\ 1.44\}.$$

[9] Digital-by-default service design reduces touch time but not due-process; see UK GDS service manual and EU eID frameworks [**EU-eIDAS-2024**, (259)].

[10] Model time standards and weighted-caseload studies provide adjudication hours by case type; we use conservative whole-system hours (judge+clerks) [(260), (261)].

[11] Prosecution workload models (APRI/NDAA) guide staffing by case complexity; we adopt conservative averages [(262), (263)].

[12] OECD legal needs surveys indicate high prevalence of justiciable problems; we size a conservative floor of assisted matters [(254)].

E) Channel support & float

Front-office guidance/e-filing help: $\{1.5, 1.0, 0.8\}$ h/wk/1,000.[13] Training/QA float: +10% of subtotal.

Totals

$$H_{\text{subtotal}} = H_{\text{registry}} + H_{\text{courts}} + H_{\text{pros}} + H_{\text{aid}} + H_{\text{support}},$$
$$H_{\text{total}} = 1.10 \cdot H_{\text{subtotal}} = \{\mathbf{13.55}, \mathbf{8.44}, \mathbf{5.99}\} \text{ h/wk/1,000.}$$

Results (weekly hours per 1,000; rounded)

Table 20.1: Administration & justice: conservative weekly hours per 1,000 residents.

Scenario	IDs/Registries	Courts	Prosecution	Legal aid	Channel support	**Total**
Low automation	3.61	3.46	0.87	2.88	1.50	**13.55**
Medium automation	1.77	**2.40**	0.58	1.92	1.00	**8.44**
High automation	1.04	1.73	0.43	1.44	0.80	**5.99**

Notes. Clearance $\geq$ 100% enforced. If local inflow differs, scale the inflow drivers. Due-process tasks do not shrink with automation; savings come from straight-through processing of routine filings and assisted digital channels.

[13] Digital front doors reduce counter load but require assisted digital for equity [(259)].

21 Public Governance Stack

21.1 Scope, Floors, Boundary

Floors.

- **Elections.** In-person polling with paper trail (used for conservative calculation only) and chain-of-custody; one polling place per ∼1,000 voters; trained poll workers; accessible voting.[1]
- **Stats/Planning/Optimization.** Open methods, reproducible statistics, and published plans; minimum municipal analytical capacity; national coordination.[2]
- **Procurement.** Competitive, transparent awards; publication of contracts and performance; e-procurement by default.[3]
- **Inspection/Regulation.** Risk-based inspections; clear service charters; separation of advice and sanction.[4]
- **Cybersecurity.** Baseline ISMS; SOC coverage; incident reporting; continuity.[5]
- **Land/Cadastre/Permitting.** Fit-for-purpose land admin; digital cadastre; time-bound building permits; open geodata.[6]
- **Audit/Ombuds.** Independent supreme audit and ombuds offices; open findings; protected petition channels.[7]

Boundary. Direct public-sector hours: poll workers, registry and planning analysts, procurement officers, inspectors, cyber teams, cadastral/permitting staff, auditors/ombuds.

Transaction drivers (per 1,000; conservative defaults)

- Elections: general + local every 4 years (staggered), referendum every 8 years. One polling place per ∼1,000 voters; ∼8 poll workers/event; day length 16 h; setup/count/training 8 h/worker/event.[8]
- Statistics/Planning/Optimization: baseline municipal analytics team sized to **1 analyst per 20,000** population (shared regionally) plus national NSO share.[9]
- Procurement: **4 contract awards**/1,000/year across goods/services/works via e-procurement (conservative floor).[10]

[1]International IDEA and OSCE/ODIHR handbooks define polling-station staffing, accessibility, and chain-of-custody good practice. [(264), (265)]
[2]PARIS21 and OECD guidance anchor minimum analytical capacity and evidence-informed policy. [(266), (267)]
[3]OECD procurement principles and toolbox. [(268), (269)]
[4]OECD Regulatory Enforcement and Inspections Toolkit. [(270)]
[5]ENISA SOC good practices and NIST NICE workforce framework. [(271), (272)]
[6]UN-GGIM Framework for Effective Land Administration; FAO VGGT. [(273), (274)]
[7]INTOSAI principles and IOI standards. [(275), (276)]
[8]Polling-station staffing from IDEA/IFES practice; observation manuals align on 6–10 workers/station and long-day operations. [(264), (277)]
[9]PARIS21 capacity diagnostics show low analyst density; we fix a conservative floor at municipal level and assume national support. [(266)]
[10]Contract counts scale with spend and service scope; we expose counts as a driver and set a conservative baseline. [(268)]

- Inspection/Regulation: **40 regulated sites**/1,000 (food premises, workplaces, small facilities); **40%** high-risk subset inspected annually.[11]
- Land/Cadastre/Permitting: **7** major + **14** minor building permits/1,000/year; **10** cadastral transactions/1,000/year.[12]
- Audit/Ombuds: **0.2** entity audits/1,000/year; **5** ombuds cases/1,000/year.[13]

Labor coefficients (minutes or hours per transaction)

Elections (annualized). Per event: poll-station hours = 8 workers ×(16+8) = 192. With 2 events every 4 years and 1 event every 8:

$$H_{\text{elections}} = \frac{192}{52}\left(\frac{2}{4}+\frac{1}{8}\right) = \mathbf{2.31}\ \text{h/wk/1,000} \quad \text{(registry maintenance handled elsewhere).}$$

Stats/Planning/Optimization. Analyst hours per 1,000: {2.0, 1.4, 1.0} h/wk (low/med/high), covering official statistics pipelines, open-data releases, and optimization runs.[14]

Procurement. Staff hours/award {25, 12, 8} (end-to-end incl. prep, notice, evaluation, contract, publication). Weekly:

$$H_{\text{proc}} = \frac{4}{52}\cdot\{25, 12, 8\} = \{\mathbf{1.92},\ \mathbf{0.92},\ \mathbf{0.62}\}.$$

Inspection/Regulation. Inspection hours/visit {4, 3, 2} incl. travel; follow-up share = 50% at 1 h. Annual hours = 40 × 40% × ($h_{\text{insp}} + 0.5$); weekly:

$$H_{\text{insp}} = \frac{40\cdot 0.4\cdot(\{4,3,2\}+0.5)}{52} = \{\mathbf{1.38},\ \mathbf{1.08},\ \mathbf{0.77}\}.$$

Cybersecurity. Local ISMS manager = {0.8, 0.6, 0.5} h/wk; regional SOC share = {0.8, 0.7, 0.5} h/wk. Total:

$$H_{\text{cyber}} = \{\mathbf{1.6},\ \mathbf{1.3},\ \mathbf{1.0}\}.$$ [15]

Land/Cadastre/Permitting. Staff hours/permit: major $\{6, 3, 1.5\}$, minor $\{2, 1.5, 1\}$; cadastral transaction $\{0.5, 0.3, 0.2\}$.

$$H_{\text{land}} = \frac{7\cdot\{6,3,1.5\}+14\cdot\{2,1.5,1\}+10\cdot\{0.5,0.3,0.2\}}{52} = \{\mathbf{1.44},\ \mathbf{0.87},\ \mathbf{0.51}\}.$$

Audit/Ombuds. Entity audit hours $\{80, 60, 40\}$ at 0.2/y; ombuds case hours $\{3, 2, 1.5\}$ at 5/y.

$$H_{\text{audit}} = \frac{0.2\cdot\{80,60,40\}+5\cdot\{3,2,1.5\}}{52} = \{\mathbf{0.60},\ \mathbf{0.42},\ \mathbf{0.29}\}.$$

Open-data & transparency. Publication and helpdesk: fixed **0.3** h/wk (all scenarios).[16]

[11] Risk-based coverage in OECD toolkit typically inspects a priority subset annually. [(270)]
[12] Building and cadastral volumes vary; we set conservative floors and keep formulas visible. [(273)]
[13] Performance/entity audit cadence and complaint volumes are parameterized; references set principles not quotas. [(275), (276)]
[14] Data-driven governments require recurring analytics; we set a conservative floor. [(267)]
[15] SOC staffing and NICE roles; municipal ISMS per ISO/NIST with shared SOC reduces per-capita load. [(271), (272)]
[16] International Open Data Charter encourages continuous publication; small steady hours suffice. [(278)]

Summary (weekly hours per 1,000; rounded)

Table 21.1: Public governance stack: conservative weekly hours per 1,000 residents.

Scenario	Elections	Stats	Procurement	Inspection	Cyber	Land.	Audit.	Data	**Total**
Low	2.31	2.00	1.92	1.38	1.60	1.44	0.60	0.30	**11.6**
Medium	2.31	1.40	0.92	1.08	1.30	0.87	0.42	0.30	**8.6**
High	2.31	1.00	0.62	0.77	1.00	0.51	0.29	0.30	**6.8**

22 Standards, Metrology & Accreditation

22.1 Scope, Floors, Boundary

Floors.

- **Accredited labs.** Testing & calibration to **ISO/IEC 17025**[1] with traceability to SI via NMI/ILC.[2]
- **Regulatory baselines.** Drinking-water surveillance per WHO/EU; food hygiene per Codex; official controls per EU 2017/625.[3]
- **Medical devices.** Periodic safety/accuracy checks on patient-connected equipment.[4]
- **Legal metrology.** In-service verification of trade instruments to OIML/NIST handbooks.[5]
- **Governance.** Accreditation body to ISO/IEC 17011; inspection bodies to ISO/IEC 17020; product certification to ISO/IEC 17065; code participation (ISO/IEC/ASTM).[6]

Boundary. Direct local hours: sampling, analysis, calibration, verification, QC/QA, method validation upkeep, accreditation audits, and code-work. Heavy capex and national metrology institute (NMI) core staff are upstream and allocated via the *MRO* chapter; only their *traceability share* appears here.

Coverage drivers (per 1,000; conservative)

- **Water lab.** 1 distribution microbiology sample/week (*E. coli*, coliform) + 1 phys–chem panel/month.[7]
- **Wastewater sentinel.** 1 composite sample/week for pathogens/chem markers.[8]
- **Food official controls.** 2 samples/week across retail/caterers for hygiene/pathogens/allergens.[9]
- **Materials & construction tests.** 3 tests/week on aggregates, concrete, soils, or timber for municipal works and supplier QA (steady baseline).[10]
- **Medical devices.** Periodic verification pool covering basic clinic inventory (infusion pumps, sphygmomanometers, thermometers, scales) ⇒ steady *0.8 h/wk*.[11]
- **Legal metrology.** In-service verification of small trade instruments ⇒ steady *0.5 h/wk*.[12]
- **Reference traceability.** Participation in ILCs / shipment to NMI: *0.2 h/wk* (pooled regionally).[13]

[1] Competence, impartiality, consistent operation of labs [(279)].
[2] BIPM SI Brochure; ILAC MRA for international acceptance [(280), (281)].
[3] WHO *Guidelines for Drinking-water Quality*; EU Drinking Water Directive; Codex CXC 1-1969; EU Reg. 2017/625 [(282), (283), (284), (285)].
[4] WHO medical device maintenance outlines periodic verification needs [(286)].
[5] Weights/measures per OIML R111 and national handbooks [(287), (288)].
[6] Standards for accreditation, inspection, certification [(289), (290), (291)].
[7] WHO/EU surveillance imply at least weekly micro in small networks; monthly phys–chem minimums [(282), (283)].
[8] Composite sampling and lab analysis per public health surveillance norms.
[9] Codex hygiene + EU official controls—risk-based but continuous [(284), (285)].
[10] Coverage placeholder; project spikes sit in sector build chapters.
[11] WHO device maintenance; many items are annual/biannual checks [(286)].
[12] OIML/NIST practice for small-scale trades [(287), (288)].
[13] ILAC MRA and EURAMET/AFRIMETS intercomparisons justify small steady effort [(281)].

- **Accreditation & codes.** ISO/IEC 17011 surveillance, assessor time, and code participation: *0.3 h/wk.*[14]

Labor coefficients (analytical minutes per unit; overhead on non-contact)

Minutes per test (low/med/high denote digital/LIMS overhead cuts, not analyst throughput):

$$\begin{aligned}&\text{Water micro} = (90, 90, 90), \quad \text{Water phys–chem (panel)} = (120, 120, 120),\\ &\text{Wastewater composite} = (60, 60, 60), \quad \text{Food sample} = (75, 75, 75),\\ &\text{Materials test} = (60, 60, 60).\end{aligned}$$

Non-contact overhead multipliers on *lab blocks only* (QA records, LIMS, chain-of-custody, reporting):

$$\mu = \{+25\%,\ +15\%,\ +8\%\} \quad \text{(low, med, high)}.$$

Calculation log (weekly h per 1,000)

A) Raw analytical time

$$\begin{aligned}&H_{\text{water}} = \tfrac{90}{60} \times 1 + \tfrac{120}{60} \times \tfrac{1}{4} = 1.5 + 0.5 = 2.0 \text{ h/wk},\\ &H_{\text{waste}} = \tfrac{60}{60} \times 1 = 1.0,\\ &H_{\text{food}} = \tfrac{75}{60} \times 2 = 2.5,\\ &H_{\text{mat}} = \tfrac{60}{60} \times 3 = 3.0,\\ &H_{\text{med}} = 0.8, \quad H_{\text{legal}} = 0.5, \quad H_{\text{trace}} = 0.2, \quad H_{\text{accr}} = 0.3.\end{aligned}$$

Lab subtotal subject to overhead: $H_{\text{lab}} = H_{\text{water}} + H_{\text{waste}} + H_{\text{food}} + H_{\text{mat}} + H_{\text{med}} + H_{\text{legal}} = 9.8$.

B) Apply overhead μ to lab subtotal; add fixed pools

$$\begin{aligned}&H_{\text{core}} = \{9.8 \times 1.25,\ 9.8 \times 1.15,\ 9.8 \times 1.08\} = \{12.25,\ 11.27,\ 10.58\},\\ &H_{\text{total}} = H_{\text{core}} + H_{\text{trace}} + H_{\text{accr}} = \{\mathbf{12.8},\ \mathbf{11.8},\ \mathbf{11.1}\} \text{ h/wk/1,000}.\end{aligned}$$

Results (weekly hours per 1,000; rounded)

Table 22.1: Standards, metrology & accreditation: conservative weekly hours per 1,000 residents.

Scenario	Water	Wastewater	Food	Materials	Med	Legal	Traceability	Accred.	**Total**
Low	2.5	1.3	3.1	3.8	1.0	0.6	0.2	0.3	**12.8**
Medium	2.3	1.2	2.9	3.5	0.9	0.6	0.2	0.3	**11.8**
High	2.2	1.1	2.7	3.3	0.9	0.5	0.2	0.3	**11.1**

Note. Scenario deltas reflect lower non-contact overheads (LIMS, e-signatures, e-chain-of-custody). Analytical minutes per test are held constant for conservatism.

[14] Accreditation cycles and standards committees require recurring hours [(289)].

23 Training & Job Guarantees

Objective: size *weekly human hours per 1,000 residents* for paid retraining and apprenticeships. We report a **Ramp** phase to transition workers into foundational sectors and a **Steady** phase for replacement/upskilling. Contact learning and mentoring time is protected; automation trims only admin/records.

23.1 Scope, Floors, Boundary

Floors.

- Paid training and apprenticeships; no unpaid work. Job-guarantee placements are waged.
- Apprenticeships mix workplace learning with ∼20–40% off-the-job instruction.[1]
- Short-course reskilling uses modular credentials sized via EU VET conventions (25–30 learning-hours per credit).[2]
- Administrative and QA overhead is explicit and conservative.

Boundary. Hours include off-the-job instruction, mentoring/supervision overhead for apprentices, program admin/QA, and a small pool for job-guarantee supervision during early placement. *Apprentices' productive on-the-job hours sit inside sector chapters, not here.*

Population anchors (per 1,000; conservative)

Working-age share = 65% ⇒ 650 persons;[3] labor-force participation = 60% ⇒ **L** = **390** workers.[4]

Scenario coefficients

Low automation: Ramp retraining rate = 8% of L/year (5 years). Steady = 3%/year. Apprentice share = 30%. Short-course size = 500 h/trainee.[5]

Medium automation: Ramp = 6%/y; Steady = 2%/y. Apprentice share = 40%. Short-course = 400 h.

High automation: Ramp = 4%/y; Steady = 1.5%/y. Apprentice share = 50%. Short-course = 300 h.

Common anchors: full-time = 40 h/week, 48 paid weeks/year; apprentice off-the-job share = 20% ⇒ $0.2 \times 40 \times 48 = 384$ h/year.[6] Mentor overhead on apprentice time = $\{10\%, 8\%, 7\%\}$ of annual working hours (low/med/high). Admin/QA overhead on training blocks = $\{+15\%, +12\%, +10\%\}$. Job-guarantee supervision pool = 0.5 h/week per new trainee over first 12 weeks.[7]

[1] [**ILO-QualityApprenticeships-2017**, **OECD-7Questions-2018**].
[2] [**CEDEFOP-ECVET-Guide**].
[3] [(203)].
[4] [**ILOSTAT-LFPR-2024**].
[5] Modular certificates of ∼20 ECVET credits ≈ 500 hours at 25 h/credit [**CEDEFOP-ECVET-Guide**].
[6] [**ILO-QualityApprenticeships-2017**, **OECD-7Questions-2018**].
[7] Public employment programme guidance recommends structured supervision in early placements [**ILO-EIIP-2019**, **OECD-PES-2021**].

Calculation log (per 1,000 residents)

Let $L = 390$. For a given annual retraining rate r, trainees/year $n = L\,r$. Split by apprentice share s_{ap} and short-course share $s_{sc} = 1 - s_{ap}$.

Short-course off-the-job.

$$H_{\mathrm{SC/wk}} = \frac{n\, s_{sc}\, h_{\mathrm{SC}}}{52}.$$

Apprenticeship components. Off-the-job:

$$H_{\mathrm{AP,off/wk}} = \frac{n\, s_{ap} \cdot 384}{52}.$$

Mentor overhead:

$$H_{\mathrm{mentor/wk}} = \frac{n\, s_{ap} \cdot (\phi_{\mathrm{mentor}} \cdot 40 \cdot 48)}{52}, \quad \phi_{\mathrm{mentor}} \in \{0.10, 0.08, 0.07\}.$$

Program overhead. Apply admin/QA to training blocks (SC + AP-off + mentor):

$$H_{\mathrm{overhead}} = \mu \cdot (H_{\mathrm{SC/wk}} + H_{\mathrm{AP,off/wk}} + H_{\mathrm{mentor/wk}}), \quad \mu \in \{0.15, 0.12, 0.10\}.$$

Job-guarantee supervision.

$$H_{\mathrm{JG/wk}} = n \cdot \left(\frac{12}{52}\right) \cdot 0.5.$$

Total (weekly).

$$H_{\mathrm{total}} = H_{\mathrm{SC/wk}} + H_{\mathrm{AP,off/wk}} + H_{\mathrm{mentor/wk}} + H_{\mathrm{overhead}} + H_{\mathrm{JG/wk}}.$$

Summary (weekly hours per 1,000; rounded)

Table 23.1: Training & job guarantees: Ramp and Steady weekly hours per 1,000 residents.

Phase	Scenario	Short-course	Appr. off-job	Mentor	Admin/QA	JG supervis.	Total
Ramp	Low	210.0	69.1	34.6	47.1	3.6	**364.3**
	Medium	108.0	69.1	27.6	24.6	2.7	**232.0**
	High	45.0	57.6	20.2	12.3	1.8	**136.8**
Steady	Low	78.8	25.9	13.0	17.6	1.4	**136.6**
	Medium	36.0	23.0	9.2	8.2	0.9	**77.3**
	High	16.9	21.6	7.6	4.6	0.7	**51.3**

Notes. Ramp runs ∼5 years; then steady-state holds replacement/upskilling. If your labor force differs from 390/1,000, scale linearly. If off-the-job share exceeds 20%, hours rise proportionally.

24 International Coordination & Trade

24.1 Scope, Floors, Boundary

Floors.

- **Trade facilitation.** Pre-arrival processing, risk management, paperless flows, AEO recognition.[1]
- **Performance discipline.** Measure and fix bottlenecks with Time Release Studies; coordinated border management with other agencies.[2]
- **Digital single window.** Interoperable customs, post/express, SPS, port.[3]
- **Treaties & representation.** Vienna Convention compliance, transparent negotiation briefs.[4]
- **Aid logistics readiness.** Stockpile interfaces and cluster participation.[5]

Boundary. Direct government hours: documentary clearance, physical inspections, post-clearance audit, AEO/risk, single-window ops, interagency coordination, treaty work, and aid-logistics readiness. Port/airport terminal labor and freight carriers are counted in *Freight & Warehousing*.

Transaction drivers (per 1,000; conservative)

Annual volumes:

$$\begin{aligned}&\text{Commercial declarations: imports 40, exports 15, transit 10 (total } D\text{=65).}\\&\text{Postal/express items requiring customs: 600.}\\&\text{Post-clearance audits: 1 per 200 decls (documentary focus).}\\&\text{Aid consignments: 0.05 /y (steady readiness maintained).}\end{aligned}$$

Rationales: single-window systems collapse touch-time; inspections are risk-targeted; postal flows are bulk-cleared with data capture.[6]

Labor coefficients (conservative)

Minutes per transaction (low/med/high):

$$\begin{aligned}&\text{Documentary clearance (per decl.): (60, 30, 15),}\\&\text{Physical inspection share of decl.: (10\%, 5\%, 2\%) at (120, 90, 60) min/inspection,}\\&\text{Postal/express item: (5, 3, 2) min (data-driven bulk release),}\\&\text{Post-clearance audit: (4, 3, 2) h/audit (documentary).}\end{aligned}$$

[1] WTO Trade Facilitation Agreement core measures; WCO SAFE AEO framework [(292), (293)].
[2] WCO TRS method; WCO Coordinated Border Management compendium [(294), (295)].
[3] UNCTAD ASYCUDA and single-window practice; OECD TFI evidence on time/cost gains [(296), (297)].
[4] Vienna Convention on the Law of Treaties [(298)].
[5] WFP Logistics Cluster preparedness guidance [(299)].
[6] WCO-UPU customs data exchange and risk-based clearance reduce per-item handling [(300)]. OECD TFIs link ICT/risk management to lower times [(297)].

Fixed weekly pools (h/wk/1,000): AEO/risk management {0.20, 0.15, 0.10}; single-window/IT {0.30, 0.25, 0.20}; interagency border mgmt {0.20, 0.15, 0.10}; treaties/rep. {0.30, 0.20, 0.15}; aid-logistics readiness 0.30 (all).[7]

Calculation log (weekly h per 1,000)

Let $D = 65$/y. Weekly counts: $\frac{D}{52} = 1.25$ decls/wk; postal $= \frac{600}{52} = 11.54$/wk; audits $= \frac{D}{200\times 52} =$ 0.00625/wk.

$$
\begin{aligned}
H_{\text{docs}} &= 1.25 \times \{1.0,\ 0.5,\ 0.25\} = \{1.25,\ 0.63,\ 0.31\},\\
H_{\text{insp}} &= \left(\frac{D\,s}{52}\right) \times \{2.0,\ 1.5,\ 1.0\} = \{0.25,\ 0.094,\ 0.025\},\\
H_{\text{post}} &= 11.54 \times \{5,\ 3,\ 2\}/60 = \{0.96,\ 0.58,\ 0.38\},\\
H_{\text{audit}} &= \{0.025,\ 0.019,\ 0.013\}.
\end{aligned}
$$

Add fixed pools and sum.

Summary (weekly hours per 1,000; rounded)

Table 24.1: International coordination & trade: conservative weekly hours per 1,000 residents.

Scenario	Docs	Inspections	Parcels	Audits	AEO	Window	CBM	Treaties	Aid ready	**Total**
Low	1.25	0.25	0.96	0.03	0.20	0.30	0.20	0.30	0.30	**3.80**
Medium	0.63	0.09	0.58	0.02	0.15	0.25	0.15	0.20	0.30	**2.37**
High	0.31	0.03	0.38	0.01	0.10	0.20	0.10	0.15	0.30	**1.58**

Notes. This is the *thin line* for governance only. Manufacturing, port ops, warehousing, and trucking are counted in their chapters. If flows or inspection rates are higher, scale the drivers and keep risk-based control.

[7] Risk/AEO and CBM per WCO SAFE/CBM; single-window ops per UNCTAD; aid logistics readiness per WFP [(293), (295), (296), (299)].

25 Waste & Materials

25.1 Scope, Floors, Boundary

Service floors. 100% coverage; **weekly** residual and organics collection; **biweekly** dry recycling; HHW events; safe disposal. Planning baseline waste generation **1.0 kg/person/day** (conservative vs. global mean ~0.74) [(301)]. Composition vector for planning: 40% organics, 30% recyclables (paper/card, plastics, glass, metals), 30% residuals [(302), (303)].

Boundary. Direct hours: curbside/communal collection (crews, drive time, tip time), MRF sorting, composting/AD operations, HHW events and depot, transfer station, and sanitary landfill cell ops (daily cover, compaction, gas/leachate system O&M).[1]

Inputs (per 1,000; weekly)

Total MSW $= 1.0\ \text{kg} \cdot \text{person}^{-1} \cdot \text{day}^{-1} \times 1{,}000 \times 7 = 7{,}000\ \text{kg} = 7.0\ \text{t/week}$ [(301)].
By stream (planning vector): organics = 2.8 t/wk; recyclables = 2.1 t/wk; residuals = 2.1 t/wk.

Labor coefficients (conservative bands)

Collection productivity (tonnes per crew-hour, includes stops+driving+tip; low/med/high denote manual two/one-person rear-loader, semi-automated split, automated side-loader+route optimization).[2]

$$\begin{aligned}
&\text{Residuals } (t/\text{h}) = \{0.8,\ 1.2,\ 2.0\},\\
&\text{Organics } (t/\text{h}) = \{0.7,\ 1.0,\ 1.5\},\\
&\text{Recyclables } (t/\text{h}) = \{0.6,\ 0.9,\ 1.3\};\ \text{apply route overhead } \mu_{\text{rt}} = \{15\%, 10\%, 8\%\}.
\end{aligned}$$

MRF sorting labor (hours/tonne of inbound recyclables; includes QC, rejects handling).
{1.2, 0.8, 0.5} h/t for manual-heavy, optical+QC, optical+robotic assist MRFs [(308), (309)].

Organics processing (hours/tonne; reception, windrow turning/aeration, screening; in-vessel on the low end of labor).
{0.50, 0.35, 0.25} h/t [(310), (311)].

Landfill operations (hours/tonne; compaction, daily cover, gas/leachate checks; excludes capital cell build).
{0.20, 0.12, 0.08} h/t [**ISWA-Landfill-2015**, (305)].

Transfer station (hours/tonne; scalehouse, spotter, load-out) {0.030, 0.020, 0.015} h/t [(304)].

HHW & bulky baseline (steady pool; events+depot ops, outreach): {1.00, 0.80, 0.60} h/wk/1,000 [(312), (306)].

Admin/QA/education add-on on subtotal: $\{+10\%, +8\%, +6\%\}$ (records, compliance sampling, citizen comms).

[1] Transfer: small steady pool even where direct haul is feasible [(304)]. Landfill ops: compaction, cover, gas/leachate; emissions controls are required [(305)].

[2] Stops/hour and tonnes/crew-hour rise strongly with containerization and automated lift; see ISWA and SWANA practice [(306), (307)].

Calculation log (weekly h per 1,000)

A) Collection

For stream $s \in \{\text{res, org, rec}\}$ with tonnage T_s and productivity p_s (t/h),

$$H_{\text{coll}} = (1 + \mu_{\text{rt}}) \sum_s \frac{T_s}{p_s}.$$

Numerical:

$$H_{\text{coll}} = \{\mathbf{11.64},\ \mathbf{7.57},\ \mathbf{4.89}\}.$$

B) Facilities and specials

$$\begin{aligned}
&H_{\text{MRF}} = 2.1 \times \{1.2, 0.8, 0.5\} = \{2.52, 1.68, 1.05\},\\
&H_{\text{compost}} = 2.8 \times \{0.50, 0.35, 0.25\} = \{1.40, 0.98, 0.70\},\\
&H_{\text{landfill}} = 2.1 \times \{0.20, 0.12, 0.08\} = \{0.42, 0.252, 0.168\},\\
&H_{\text{transfer}} = 7.0 \times \{0.030, 0.020, 0.015\} = \{0.21, 0.14, 0.105\},\\
&H_{\text{HHW+bulky}} = \{1.00, 0.80, 0.60\}.
\end{aligned}$$

C) Add admin/QA/education

$$H_{\text{total}} = (1 + \mu)\left(H_{\text{coll}} + H_{\text{MRF}} + H_{\text{compost}} + H_{\text{landfill}} + H_{\text{transfer}} + H_{\text{HHW+bulky}}\right),$$

with $\mu = \{10\%, 8\%, 6\%\}$.
Numerical totals: $\{\mathbf{18.91},\ \mathbf{12.34},\ \mathbf{7.97}\}$ h/wk/1,000.

Summary (weekly hours per 1,000; rounded)

Table 25.1: Waste & materials system: conservative weekly hours per 1,000 residents.

Scenario	Collection	MRF	Compost	Landfill	Transfer	HHW/Bulky	Admin/QA	**Total**
Low	11.64	2.52	1.40	0.42	0.21	1.00	1.72	**18.91**
Medium	7.57	1.68	0.98	0.25	0.14	0.80	0.92	**12.34**
High	4.89	1.05	0.70	0.17	0.11	0.60	0.45	**7.97**

Notes. Collection dominates unless MRFs are very manual. Raising capture of organics shifts hours from landfill to compost at roughly neutral totals. If per-capita waste exceeds 1.0 kg/day, scale linearly.

26 Animal & Plant Health

26.1 Scope, Floors, Boundary

Floors.

- **Zoonoses:** event-based and indicator surveillance; dog rabies vaccination $\geq 70\%$ annual coverage in owned/stray dogs; abattoir hygiene inspection per shift.[1]
- **Phytosanitary:** risk-based import checks, nursery/market inspections, and pest surveillance per IPPC/ISPM.[2]
- **Vector control:** integrated mosquito management (larval source reduction, larviciding, adult monitoring) and public-space rodent control.[3]

Boundary. Direct hours: field vaccination, inspection, trapping, larviciding, source reduction, and sampling. Laboratory testing and accreditation sit in *Standards & Metrology*. Port customs sits in *International Coordination & Trade*.

Inputs (per 1,000; conservative defaults)

- Dog population $D = 300$ dogs (0.3 dogs/person; parameterize locally).
- Urban vector monitoring: $N_{\text{traps}} = 2$ gravid/BG traps serviced weekly.
- Area-dependent operations are held at a thin default via traps and route hours; planners may replace with hectare-based coefficients.

Labor coefficients (conservative)

A) Rabies vaccination (minutes per dose). Low/Med/High = $(15, 10, 8)$; target coverage $\rho = 70\%$.[4]

B) Zoonoses surveillance & abattoir presence.

- Field sampling & reporting: 2 composite animal-health samples/week at 30 min each = 1.0 h/wk.[5]
- Abattoir inspection: pooled presence for local consumption share = 0.5 h/wk.[6]

C) Phytosanitary (risk-based).

- Nurseries/markets: 1 visit/month at 1 h $\Rightarrow$ 0.25 h/wk.
- Post-entry & surveillance: 2 site-hours/month $\Rightarrow$ 0.5 h/wk (low), 0.4 (med), 0.3 (high).[7]

[1] WHO rabies strategy targets $\geq 70\%$ dog vaccination; OIE/WOAH Terrestrial Code requires surveillance and official controls; Codex meat hygiene codifies operator duties and competent-authority verification [(313), (314), (315), (316)].
[2] ISPM 6 (Surveillance), ISPM 23 (Pest reporting), ISPM 31 (Sampling of consignments) [(317), (318), (319)].
[3] WHO Integrated Vector Management, ECDC *Aedes* guidance, AMCA best practices [(320), (321), (322)].
[4] Mass dog vaccination logistics routinely use 10–15 minutes/dose including registration; lower with pre-registration [(313)].
[5] Aligned with OIE/WOAH surveillance principles [(314)].
[6] Competent-authority presence per shift and verification tasks [(316), (315)].
[7] IPPC ISPM 6 and 31 frame surveillance and sampling density [(317), (319)].

D) Vector control.

- Trap servicing: 0.5 h/trap/week $\Rightarrow$ 1.0 h/wk.[8]
- Larval source mgmt/larviciding route: $\{1.0, 0.7, 0.5\}$ h/wk.
- Community source-reduction/outreach: $\{0.5, 0.3, 0.2\}$ h/wk.
- Public-space rodent control: $\{0.5, 0.4, 0.3\}$ h/wk.[9]

E) Program overhead. Admin/QA on subtotal $\mu = \{+10\%, +8\%, +6\%\}$.

Calculation log (weekly h per 1,000)

A) Rabies vaccination

$$H_{\text{rabies}} = \frac{D \cdot \rho \cdot m}{60 \cdot 52} = \left\{ \frac{300 \cdot 0.7 \cdot 15}{3120}, \frac{300 \cdot 0.7 \cdot 10}{3120}, \frac{300 \cdot 0.7 \cdot 8}{3120} \right\} = \{\mathbf{1.01}, \ \mathbf{0.67}, \ \mathbf{0.54}\}.$$

B) Zoonoses surveillance & abattoir

$$H_{\text{zoo+abb}} = \mathbf{1.0} + \mathbf{0.5} = \{\mathbf{1.5}, \ \mathbf{1.5}, \ \mathbf{1.5}\}.$$

C) Phytosanitary

$$H_{\text{phyto}} = \mathbf{0.25} + \{0.50, \ 0.40, \ 0.30\} = \{\mathbf{0.75}, \ \mathbf{0.65}, \ \mathbf{0.55}\}.$$

D) Vector control

$$H_{\text{vector}} = 1.0 + \{1.0, 0.7, 0.5\} + \{0.5, 0.3, 0.2\} + \{0.5, 0.4, 0.3\} = \{\mathbf{3.0}, \ \mathbf{2.4}, \ \mathbf{2.0}\}.$$

E) Add program overhead

Subtotal $S = \{1.01{+}1.5{+}0.75{+}3.0, \ 0.67{+}1.5{+}0.65{+}2.4, \ 0.54{+}1.5{+}0.55{+}2.0\} = \{6.26, \ 5.22, \ 4.59\}$.

$$H_{\text{total}} = (1 + \mu)S = \{\mathbf{6.89}, \ \mathbf{5.64}, \ \mathbf{4.87}\} \text{ h/wk/1,000}.$$

Summary (weekly hours per 1,000; rounded)

Table 26.1: Animal & plant health: conservative weekly hours per 1,000 residents.

Scenario	Rabies vacc.	Zoonoses+abattoir	Phytosanitary	Vector control	Admin/QA	**Total**
Low	1.01	1.50	0.75	3.00	0.63	**6.89**
Medium	0.67	1.50	0.65	2.40	0.42	**5.64**
High	0.54	1.50	0.55	2.00	0.28	**4.87**

Notes. Dog population, trap count, and area-dependent routes are explicit knobs. If dog ownership or vector risk is higher, scale those drivers. Laboratory hours are counted in *Standards & Metrology*.

[8] Trap deployment and servicing times from operational guidance [(322), (321)].
[9] Urban rodent IPM programs emphasize inspection, baiting, and sanitation cycles [(323)].

27 Sports & Recreation — Access for All

27.1 Scope, Floors, Boundary

Floors.

- **Physical activity access.** Capacity aligned to WHO weekly activity guidance: adults 150–300 min; children 60 min/day.[1]
- **Safety.** Pools supervised per HSG179/MAHC risk-based practice; constant poolside supervision; two lifeguards on duty as conservative floor.[2]
- **Coaching ratios.** Group sessions capped at **1:12** (youth), within safeguarding guidance.[3]

Boundary. Direct hours: lifeguards, facility attendants, coaching, basic cleaning, pool plant checks, turf maintenance, bookings/helpdesk. Capital build and large refurb sit in *Capital/MRO*. Laboratory water tests sit in *Standards/Metrology*.

Service bundle (per 1,000; weekly, conservative)

We provide capacity that can meet ~150 min/week for several hundred adults with headroom for youth:

Gym open-hours	$G = 56$ h/wk (8 h/day)
Pool lane-hours	$L_h = 80$ lane-h/wk (e.g., 4 lanes for 20 h)
Court-hours	$C = 60$ h/wk (indoor multi-use)
Pitch-hours	$P = 20$ h/wk (grass/artificial)
Coached sessions	$S = 12$ sessions/wk, 60 min each, 1:12 ratio

Note. A 25 m, four-lane pool at 20 open hours gives 80 lane-hours; lap lanes support ~ 6 swimmers/lane-hour, yielding 480 person-hours/week. Combined with gym/court/pitch capacity this satisfies WHO access floors.

Labor coefficients (conservative bands)

Scenarios (low/med/high) reflect admin/cleaning automation; safety cover does not shrink.

Pool supervision & plant.

$$\text{Lifeguard-hours} = 0.5 \times L_h \quad \text{(two lifeguards for a 4-lane pool)},$$

pool-plant checks $= \{7, 6, 5\}$ h/wk.[4]

---

[1] WHO guidelines on physical activity and sedentary behaviour [(324)].

[2] HSE HSG179 and CDC Model Aquatic Health Code emphasize risk assessment, zones, and constant supervision; we set a conservative two-lifeguard minimum when open [(325), (326)].

[3] Safeguarding supervision ratios from NSPCC/CPSU and UK Coaching; many NGBs advise 1:8 to 1:12 depending on age [(327), (328)].

[4] Constant supervision and daily plant checks per HSG179/MAHC; we hold lifeguards fixed and trim plant admin modestly [(325), (326)].

Gym. Duty supervisor per open-hour = $\{1.0,\ 0.75,\ 0.50\} \times G$.[5] Cleaning per open-hour = $0.10 \times G$ scaled by cleaning tech factor $\{1.0,\ 0.8,\ 0.6\}$.[6]

Courts. Attendant = $0.10 \times C$; cleaning = $0.05 \times C$ scaled by $\{1.0,\ 0.8,\ 0.6\}$.

Pitches. Steward during use = $0.05 \times P$; turf maintenance baseline = 2 h/wk.[7]

Coaching. S coach-hours/week; session length 60 min; ratio 1:12.

Admin/booking/helpdesk. Overhead on subtotal = $\{+15\%, +10\%, +8\%\}$.

Calculation log (weekly h per 1,000)

A) Pool

$$H_{\text{pool}} = 0.5L_h + \{7, 6, 5\} = \{40 + 7,\ 40 + 6,\ 40 + 5\} = \{47, 46, 45\}.$$

B) Gym

Supervisor $= \{1.0, 0.75, 0.50\} \cdot 56 = \{56, 42, 28\}$. Cleaning $= 0.10 \cdot 56 \cdot \{1, 0.8, 0.6\} = \{5.6, 4.48, 3.36\}$.

$$H_{\text{gym}} = \{61.6,\ 46.48,\ 31.36\}.$$

C) Courts & pitches

Courts: attendant $= 0.10 \cdot 60 = 6$; cleaning $= 0.05 \cdot 60 \cdot \{1, 0.8, 0.6\} = \{3, 2.4, 1.8\}$. Hence

$$H_{\text{courts}} = \{9,\ 8.4,\ 7.8\}.$$

Pitches: steward $= 0.05 \cdot 20 = 1$; turf $= 2$. Thus $H_{\text{pitches}} = 3$ (all scenarios).

D) Coaching

$$H_{\text{coach}} = S = 12.$$

E) Overhead

Subtotal $S = \{47 + 61.6 + 9 + 3 + 12,\ 46 + 46.48 + 8.4 + 3 + 12,\ 45 + 31.36 + 7.8 + 3 + 12\} = \{132.6,\ 115.88,\ 99.16\}$.

$$H_{\text{total}} = (1 + \mu)S = \{\mathbf{152.5},\ \mathbf{127.5},\ \mathbf{107.1}\}\ \text{h/wk/1,000}.$$

[5] Conservative staffing aligned to ACSM/IHRSA facility standards; remote access control can reduce but not remove human cover [(329)].

[6] Custodial staffing norms (APPA) with reductions from auto-scrubbers and planned tasks [(211)].

[7] Sports turf maintenance cycles from SFMA/FA pitch care guidance [(330), (331)].

Summary (weekly hours per 1,000; rounded)

Table 27.1: Sports & recreation: conservative weekly hours per 1,000 residents.

Scenario	Pool	Gym	Courts	Pitches	Coaching	Admin	**Total**
Low	47.0	61.6	9.0	3.0	12.0	19.9	**152.5**
Medium	46.0	46.5	8.4	3.0	12.0	11.6	**127.5**
High	45.0	31.4	7.8	3.0	12.0	7.9	**107.1**

Notes. Lifeguard cover is fixed. Automation reduces admin and cleaning only. If your bundle (G, L_h, C, P, S) differs, apply the replication formulas.

28 Hospitality

28.1 Scope, Floors, Boundary

Floors. Weekly prepared-meal access and limited room-nights for visitors/relatives. HACCP/Food Code practices apply.[1]

Boundary. Direct hours: kitchen/FOH service, dish/clean, check-in/front desk.

Service bundle (per 1,000; weekly, conservative)

Meals $M = 500$ prepared/served; room-nights $R = 40$.

Labor coefficients (conservative bands)

Meals-per-labor-hour (kitchen+FOH): {3.0, 5.0, 7.0}; dish/clean per meal (h): {0.10, 0.07, 0.05}.[2]

Housekeeping rooms/h: {1.2, 1.6, 2.0}; FOH check-in per room-night (h): {0.10, 0.08, 0.06}; laundry per room-night (h): {0.08, 0.06, 0.05}.[3]

Admin/QA add-on: $\{+12\%, +10\%, +8\%\}$; fixed safety/food-hygiene pool: 2 h/wk.[4]

Calculation log (weekly h per 1,000)

A) Meals

$$H_{\text{meals}} = \frac{M}{\text{MPLH}} + M \cdot h_{\text{clean/meal}} = \{\mathbf{216.7},\ \mathbf{135.0},\ \mathbf{96.4}\}.$$

B) Lodging

$$H_{\text{lodg}} = \frac{R}{\text{rooms/h}} + R \cdot (h_{\text{FOH}} + h_{\text{laundry}}) = \{\mathbf{40.5},\ \mathbf{30.6},\ \mathbf{24.4}\}.$$

C) Overhead & total

$$H_{\text{total}} = (1 + \mu)\,(H_{\text{meals}} + H_{\text{lodg}}) + 2 = \{\mathbf{290.1},\ \mathbf{184.2},\ \mathbf{132.5}\}.$$

[1] ISSA task-time compendium for cleaning benchmarks; FDA Food Code sets food-safety operations [**FDA-FoodCode-2022**, (210)].

[2] Full-service throughput bands reflect conservative service pacing; cleaning times per ISSA [(210)].

[3] Room-turn productivities consistent with custodial/roomcare ranges; see ISSA [(210)].

[4] HACCP documentation and fire/life-safety checks require recurring time [**FDA-FoodCode-2022**].

Summary (weekly hours per 1,000; rounded)

Table 28.1: Hospitality: conservative weekly hours per 1,000 residents.

Scenario	Meals	Lodging	Admin/QA	Safety	**Total**
Low	216.7	40.5	31.0	2.0	**290.1**
Medium	135.0	30.6	16.6	2.0	**184.2**
High	96.4	24.4	9.7	2.0	**132.5**

29 Retail

29.1 Scope, Floors, Boundary

Floors. Store open-hours with floor presence; staffed checkout capacity for ∼1.2 transactions/person/week.[1]
Boundary. Direct hours: floor presence, cleaning, checkout, receiving/replenishment, admin.

Service bundle (per 1,000; weekly)

Open-hours G=84; transactions T=1,200.

Labor coefficients

Presence per open-hour: $\{1.5, 1.2, 1.0\}$; cleaning per open-hour $= 0.05 \cdot \{1, 0.8, 0.6\}$ h.[2] Checkout rate (tx/h/lane): $\{12, 18, 25\}$; replenishment per transaction (h): $\{0.040, 0.030, 0.020\}$.[3] Admin add-on: $\{+10\%, +8\%, +6\%\}$; loss-prevention/QA pool: 2 h/wk.

Calculation & results

$$H_{\text{floor}} = 84 \cdot \{1.5, 1.2, 1.0\} + 84 \cdot 0.05 \cdot \{1, 0.8, 0.6\} = \{\mathbf{130.2}, \mathbf{104.2}, \mathbf{86.5}\},$$
$$H_{\text{checkout}} = \frac{T}{\{12,18,25\}} = \{\mathbf{100.0}, \mathbf{66.7}, \mathbf{48.0}\},$$
$$H_{\text{repl}} = T \cdot \{0.040, 0.030, 0.020\} = \{\mathbf{48.0}, \mathbf{36.0}, \mathbf{24.0}\},$$
$$H_{\text{sub}} = H_{\text{floor}} + H_{\text{checkout}} + H_{\text{repl}}, \quad H_{\text{total}} = (1 + \mu)H_{\text{sub}} + 2.$$

Table 29.1: Retail: conservative weekly hours per 1,000 residents.

Scenario	Floor+Clean	Checkout	Replenish	Admin	LP/QA	**Total**
Low	130.2	100.0	48.0	27.8	2.0	**308.0**
Medium	104.2	66.7	36.0	16.6	2.0	**225.4**
High	86.5	48.0	24.0	9.5	2.0	**170.0**

[1] Retail floor presence and cleaning from custodial norms; checkout efficiency from industry consortia practice [**ECR-Checkout**, (211)].
[2] Custodial productivity bands per APPA [(211)].
[3] Checkout throughput and lean restocking practice [**ECR-Checkout**, **NRF-StoreOps**].

30 Personal Services

30.1 Scope, Floors, Boundary

Access floor. Walkable salon/barber and tailoring access weekly; mobile services fill gaps.

Boundary. Direct hours: on-chair/table service, fittings, sanitation/cleanup, mobile travel/setup.

Inputs (planning defaults, per 1,000; weekly)

Jobs/week vector J (conservative, supports access without queues):

$$\text{Haircuts } 150,\ \text{Beard trims } 60,\ \text{Manicures } 100,\ \text{Pedicures } 60,\ \text{Tailoring } 50,\ \text{Beauty/waxing } 60.$$

Haircut demand aligns with 2–6 week cycles for many clients; we size near the upper end.[(332)]

Labor coefficients (minutes/job MPLH)

Use lower productivities when sources differ.

Haircuts. Full-service: 45–60 min typical; clipper shops 11–16 min target without wash.[(333), (334)] Bands (low/med/high) $\Rightarrow (45, 30, 20)$ min.

Beard trims. $(20, 15, 10)$ min (shop practice; faster in clipper formats).[(335)]

Manicure. $(45, 35, 30)$ min for basic/gel without art (booking norms).[(336)]

Pedicure. $(60, 50, 45)$ min standard.[(337), (338)]

Tailoring/alterations. Simple repairs/hemming and light zipper work show 10–60 min task times; we adopt a conservative composite $(45, 35, 30)$ min per job.[(339), (340)]

Beauty/waxing/facial short services. $(45, 30, 20)$ min (booking norms).[**SalonBusiness-Clients**]

Travel & setup overhead. Share of mobile jobs and default cleanup time:

$$\text{Mobile share } s = \{20\%, 10\%, 5\%\}, \quad \text{travel/setup } = 15\,\text{min/mobile job}, \quad \text{cleanup } = \{5, 4, 3\}\,\text{min/job}.$$

Modern booking tools expose explicit cleanup and gap/processing blocks, reducing admin slack.[(341), (342), (343), (344)]

Admin/scheduling overhead. Add on subtotal: $\{+10\%, +8\%, +6\%\}$, reflecting automation of reminders, waitlists, and rescheduling.[(345), (346)]

Calculation log (weekly h per 1,000)

Let m_k be minutes/job for service k, J_k jobs/week.

A) Service hours (on-chair/table)

$$H_{\text{svc}} = \sum_k \frac{J_k \cdot m_k}{60}.$$

Numerical (low/med/high) with the inputs above:

$$H_{\text{svc}} = \{\mathbf{350.0},\ \mathbf{257.5},\ \mathbf{200.0}\}.$$

Breakdown (h/wk):
Low: hair 112.5, beard 20.0, manicure 75.0, pedicure 60.0, tailoring 37.5, beauty 45.0.
Med: hair 75.0, beard 15.0, manicure 58.3, pedicure 50.0, tailoring 29.2, beauty 30.0.
High: hair 50.0, beard 10.0, manicure 50.0, pedicure 45.0, tailoring 25.0, beauty 20.0.

B) Travel/setup & cleanup

Total jobs $J_{\text{tot}} = \sum_k J_k = 480$.

$$H_{\text{trav+clean}} = \frac{J_{\text{tot}} \cdot (15s + c)}{60}, \quad c \in \{5, 4, 3\} \text{ min.}$$

Numerical:

$$H_{\text{trav+clean}} = \{\mathbf{64.0},\ \mathbf{44.0},\ \mathbf{30.0}\}.$$

C) Add admin/scheduling

$$H_{\text{total}} = (1 + \mu) \cdot (H_{\text{svc}} + H_{\text{trav+clean}}), \quad \mu \in \{0.10, 0.08, 0.06\}.$$

Totals:

$$\{\mathbf{455},\ \mathbf{326},\ \mathbf{244}\} \text{ h/wk/1,000 (rounded).}$$

Results (weekly hours per 1,000; rounded)

Table 30.1: Personal services: conservative weekly hours per 1,000 residents.

Scenario	Hair	Beard	Manicure	Pedicure	Tailoring	Beauty	Travel+Clean	Admin	**Total**
Low	112.5	20.0	75.0	60.0	37.5	45.0	64.0	41.4	**455**
Medium	75.0	15.0	58.3	50.0	29.2	30.0	44.0	24.1	**326**
High	50.0	10.0	50.0	45.0	25.0	20.0	30.0	13.8	**244**

Notes. Presence floors can override very high MPLH. If local demand differs, scale jobs/week and recompute.

31 Culture, Arts, Libraries & Heritage

31.1 Scope, Floors, Boundary

Floors. Public library open evenings/weekends per IFLA guidance; at least one weekly cinema programme, theatre night, and music event locally; museums/galleries open weekly.[1] Event safety and stewarding meet recognised guidance.[2]

Boundary. Direct hours: FOH (duty, ushers, box office, stewards), BOH (projection/tech), cleaning turnovers, basic programming/marketing, and museum/gallery attendants. Preventive conservation is included. Capital build and fit-out sit in *Capital/MRO*. Lab testing sits in *Standards/Metrology*.

Service bundle (per 1,000; weekly, conservative)

Library open-hours: 56 h/wk	(eves/weekends)
Museum/Gallery open-hours: 28 h/wk	
Cinema screenings: 14 per wk	(2 per day)
Theatre performances: 3 per wk	
Music venue gigs: 2 per wk	

Digital cinema servers allow automated playlists; a technician still verifies show readiness.[3] FOH/stewarding scales with hall size per safety guidance.[4]

Labor coefficients (conservative)

Low/Medium/High reflect admin automation; contact cover is not reduced.

Libraries. Presence per open-hour $= \{1.5, 1.2, 1.0\}$ staff/h; cleaning per open-hour $= \{0.10, 0.08, 0.06\}$ h (scaled by cleaning tech factor $\{1.0, 0.8, 0.6\}$); programming support $= \{4.5, 3.75, 3.0\}$ h/wk (three sessions incl. prep).[5]

Museum/Gallery attendants. Presence per open-hour $= \{1.5, 1.2, 1.0\}$ staff/h; cleaning per open-hour $= \{0.08, 0.06, 0.05\}$ h (scaled).[6]

Cinema (per screening). FOH block $= \{5.0, 3.75, 3.0\}$ h (ushers/box incl. pre/post); BOH tech $= \{0.5, 0.3, 0.2\}$ h; cleaning turnover $= \{0.5, 0.4, 0.3\}$ h.[7]

Theatre (per performance). FOH (duty+ushers) $= \{15, 12, 9\}$ h; BOH tech $= \{12, 10, 8\}$ h; box office $= 3$ h; cleaning $= 1$ h.[8]

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[1] IFLA *Public Library Service Guidelines* and the IFLA/UNESCO Manifesto emphasize convenient hours and equitable access [(347), (348)].

[2] ABTT *Technical Standards for Places of Entertainment*; HSE *Event Safety Guide*; The Purple Guide stewarding ratios [(349), (350), (351)].

[3] ISDCF TMS practice notes automation with retained technical oversight [(352)].

[4] ABTT/HSE/Purple Guide provide stewarding and FOH management expectations [(349), (350), (351)].

[5] IFLA stresses staffed access and programmes; presence floor held conservative [(347)].

[6] Front-of-house presence aligns with Museums Association practice [(353)].

[7] Digital cinema TMS reduces routine booth time; FOH remains for safety/customer service [(352), (349)].

[8] FOH/BOH blocks are conservative for a small municipal hall; see ABTT [(349)].

Music venue (per gig). FOH/security $= \{12, 9, 6\}$ h; tech $= \{8, 6, 4\}$ h; cleaning $= 0.5$ h.[9]

Preventive conservation. Steady pool $= 2.0$ h/wk/1,000 for monitoring, housekeeping, mounts, and documentation.[10]

Admin/marketing overhead. Add to subtotal: $\{+15\%, +10\%, +8\%\}$.

Calculation log (weekly h per 1,000)

A) Libraries

Presence $= 56 \times \{1.5, 1.2, 1.0\}$; cleaning $= 56 \times \{0.10, 0.08, 0.06\} \times \{1.0, 0.8, 0.6\}$; add programming.
$H_{\text{lib}} = \{\mathbf{94.1}, \mathbf{74.5}, \mathbf{61.0}\}$.

B) Museum/Gallery

Presence $= 28 \times \{1.5, 1.2, 1.0\}$; cleaning $= 28 \times \{0.08, 0.06, 0.05\} \times \{1.0, 0.8, 0.6\}$.
$H_{\text{mus}} = \{\mathbf{44.2}, \mathbf{34.9}, \mathbf{28.8}\}$.

C) Cinema

Per screening total $= \{5.0 + 0.5 + 0.5,\ 3.75 + 0.3 + 0.4,\ 3.0 + 0.2 + 0.3\} = \{6.0, 4.45, 3.5\}$ h.
$H_{\text{cin}} = 14 \times \{6.0, 4.45, 3.5\} = \{\mathbf{84.0}, \mathbf{62.3}, \mathbf{49.0}\}$.

D) Theatre

Per performance total $= \{15 + 12 + 3 + 1,\ 12 + 10 + 3 + 1,\ 9 + 8 + 3 + 1\} = \{31, 26, 21\}$ h.
$H_{\text{thr}} = 3 \times \{31, 26, 21\} = \{\mathbf{93.0}, \mathbf{78.0}, \mathbf{63.0}\}$.

E) Music venue

Per gig total $= \{20.5, 15.5, 10.5\}$ h.
$H_{\text{gig}} = 2 \times \{20.5, 15.5, 10.5\} = \{\mathbf{41.0}, \mathbf{31.0}, \mathbf{21.0}\}$.

F) Conservation & overhead

Conservation $= 2.0$ h/wk. Subtotal $S = H_{\text{lib}} + H_{\text{mus}} + H_{\text{cin}} + H_{\text{thr}} + H_{\text{gig}} + 2.0$.
Admin/marketing $= \{+15\%, +10\%, +8\%\}$ of S.
Totals: $\{\mathbf{412.1},\ \mathbf{311.1},\ \mathbf{242.8}\}$ h/wk/1,000.

[9] Stewarding scales with attendees; small-venue conservative floor [(350), (351)].

[10] *Benchmarks in Collections Care* and AIC preventive conservation emphasise continuous, scheduled activity [(354), (355)].

Results (weekly hours per 1,000; rounded)

Table 31.1: Culture, arts, libraries & heritage: conservative weekly hours per 1,000 residents.

Scenario	Library	Museum/Gallery	Cinema	Theatre	Music venue	Conservation	Admin	**Total**
Low	94.1	44.2	84.0	93.0	41.0	2.0	53.8	**412.1**
Medium	74.5	34.9	62.3	78.0	31.0	2.0	28.3	**311.1**
High	61.0	28.8	49.0	63.0	21.0	2.0	18.0	**242.8**

Notes. If venues are larger/capacity-driven, add steward/security hours by ratio per event guidance and re-total. If library or museum open-hours differ, scale presence linearly. Conservation pool is a floor; projects can add temporary hours.

32 Tourism (Visitor Services)

32.1 Scope & Floors

Scope. Visitor information, guided tours, light ranger/ambassador cover.
Floors. Open info desk, weekly tours, continuous monitoring.[1]

Service bundle (per 1,000; weekly)

Info centre open $H_I = 35$ h; guided tours $N_T = 2$ (2 h); ranger/ambassadors = 4 h; visitor intel/reporting = 1 h.

Labor coefficients

Info presence per open-hour: $\{1.0, 0.8, 0.6\}$; tours: 1 guide/tour (4 h total/wk);
admin add-on $\{+10\%, +8\%, +6\%\}$.

Calculation & results

$$H_{\text{sub}} = \{35, 28, 21\} + 4 + 4 + 1 = \{44, 37, 30\}, \quad H_{\text{total}} = (1 + \mu)H_{\text{sub}} = \{\mathbf{48.4}, \mathbf{40.0}, \mathbf{31.8}\}.$$

Table 32.1: Tourism (visitor services): weekly hours per 1,000 residents.

Scenario	Info centre	Tours	Ranger/amb.	Admin	**Total**
Low	35	4	5	4.4	**48.4**
Medium	28	4	5	3.0	**40.0**
High	21	4	5	1.8	**31.8**

[1] UNWTO destination-management and service guidance; accessible tourism standards [**UNWTO-DMO**, **ISO-21902**].

33 Hobbies & Makers

33.1 Scope & Floors

Scope. Makerspace/workshop access; small classes.
Floors. Open workshop; four instructor-led sessions/week.[1]

Service bundle (per 1,000; weekly)

Open H_O=25 h; classes = $4 \times (2$ h+0.5 h prep$)$ = 10 h; tool maintenance = 2 h.

Labor coefficients

Attendant per open-hour: $\{1.0, 0.8, 0.6\}$; cleaning per open-hour $= 0.05 \cdot \{1, 0.8, 0.6\}$ h; admin add-on $\{+10\%, +8\%, +6\%\}$.

Calculation & results

$$H_{\text{open}} = 25 \cdot \{1.0, 0.8, 0.6\} + 25 \cdot 0.05 \cdot \{1, 0.8, 0.6\} = \{\mathbf{26.25}, \mathbf{21.0}, \mathbf{15.75}\},$$
$$H_{\text{sub}} = H_{\text{open}} + 10 + 2, \quad H_{\text{total}} = (1+\mu)H_{\text{sub}} = \{\mathbf{42.1}, \mathbf{35.6}, \mathbf{29.4}\}.$$

Table 33.1: Hobbies & makers: weekly hours per 1,000 residents.

Scenario	Open+Clean	Classes	Maintenance	Admin	**Total**
Low	26.3	10.0	2.0	3.8	**42.1**
Medium	21.0	10.0	2.0	2.6	**35.6**
High	15.8	10.0	2.0	1.6	**29.4**

[1] Makerspace Playbook and fablab safety norms [**Make-Playbook**, **OSHA-MachineShop**].

34 Media Production (Independent/Local)

34.1 Scope & Floors

Scope. Small studio, light video shoots, podcasts, basic post.

Floors. Open studio; two shoots/week; three podcast sessions/week; postproduction for $\sim$5 h content.[1]

Service bundle (per 1,000; weekly)

Studio open 20 h; shoots: 2×4 h; podcasts: 3×2 h; content hours = 5.

Labor coefficients

Open presence per studio-hour: $\{1.2, 1.0, 0.8\}$; cleaning: $0.10 \cdot \{1, 0.8, 0.6\}$ h/h.
Shoot staffing factor (crew per hour): $\{2.0, 1.5, 1.2\}$; podcast staffing: $\{1.5, 1.2, 1.0\}$; post hours per content hour: $\{4, 3, 2\}$. Admin: $\{+10\%, +8\%, +6\%\}$; outreach: 2 h/wk.

Calculation & results

$$H_{\text{open}} = 20 \cdot \{1.2, 1.0, 0.8\} + 20 \cdot 0.10 \cdot \{1, 0.8, 0.6\} = \{\mathbf{26.0}, \mathbf{21.6}, \mathbf{17.2}\},$$
$$H_{\text{shoot}} = 2 \cdot 4 \cdot \{2.0, 1.5, 1.2\} = \{\mathbf{16.0}, \mathbf{12.0}, \mathbf{9.6}\},$$
$$H_{\text{pod}} = 3 \cdot 2 \cdot \{1.5, 1.2, 1.0\} = \{\mathbf{9.0}, \mathbf{7.2}, \mathbf{6.0}\},$$
$$H_{\text{post}} = 5 \cdot \{4, 3, 2\} = \{\mathbf{20.0}, \mathbf{15.0}, \mathbf{10.0}\}, \quad H_{\text{sub}} = H_{\text{open}} + H_{\text{shoot}} + H_{\text{pod}} + H_{\text{post}} + 2.$$
$$H_{\text{total}} = (1 + \mu) H_{\text{sub}} = \{\mathbf{80.3},\ \mathbf{62.4},\ \mathbf{47.5}\}.$$

Table 34.1: Media production: conservative weekly hours per 1,000 residents.

Scenario	Open	Shoots	Podcasts	Post	Outreach	Admin	**Total**
Low	26.0	16.0	9.0	20.0	2.0	7.3	**80.3**
Medium	21.6	12.0	7.2	15.0	2.0	4.6	**62.4**
High	17.2	9.6	6.0	10.0	2.0	2.7	**47.5**

[1] Digital cinema/TMS automation with retained technical oversight; FOH/BOH expectations from theatre/event standards [(352), (349)].

35 Pet Services (Non-Clinical)

35.1 Scope & Floors

Scope. Grooming, walking/daycare, basic training.
Dog baseline. D=300/1,000 (parameter).[1]

Service bundle (per 1,000; weekly)

Dog grooms = 20; cat nail trims = 10; walk slots = 40 (1 h); daycare dog-days = 10; classes = 2×1.5 h + prep = 1 h.

Labor coefficients

Groom (h/job): $\{1.5, 1.25, 1.0\}$; cat nails (h/job): $\{0.333, 0.25, 0.20\}$.
Walking slot (h): $\{1.0, 0.9, 0.8\}$; daycare (attendant h/dog-day) = 0.5; training (as above).
Mobile share on grooms+nails: $\{30\%, 20\%, 10\%\}$ at 15 min/job; admin add-on $\{+10\%, +8\%, +6\%\}$; compliance/sanitation pool = 1 h.[2]

Calculation & results

$$H_{\text{svc}} = \{30.0, 25.0, 20.0\} + \{3.33, 2.5, 2.0\} + \{40, 36, 32\} + 5 + 4,$$
$$H_{\text{travel}} = \{2.25, 1.50, 0.75\}, \quad H_{\text{total}} = (1+\mu)(H_{\text{svc}} + H_{\text{travel}}) + 1 = \{\mathbf{94.0}, \mathbf{80.9}, \mathbf{68.6}\}.$$

Table 35.1: Pet services (non-clinical): weekly hours per 1,000 residents.

Scenario	Groom	Cat nails	Walking	Daycare	Training	Travel	Admin	Compliance	**Total**
Low	30.0	3.3	40.0	5.0	4.0	2.3	7.4	1.0	**94.0**
Medium	25.0	2.5	36.0	5.0	4.0	1.5	5.9	1.0	**80.9**
High	20.0	2.0	32.0	5.0	4.0	0.8	4.3	1.0	**68.6**

[1] Planner knob; public-health dog baselines vary.
[2] Booking/cleanup blocks via salon scheduling tools; humane handling required [(341), (343)].

36 Synthesis: Total Results and the Shorter Week

Roll-up: weekly hours per 1,000 residents

Table 36.1: All-sector weekly human hours per 1,000 residents, by scenario.

Sector	Low	Medium	High
Food system	14,735	1,935	692
Housing & buildings	613	518	455
Utilities (electricity, water&WW, digital)	314	225	172
Care & learning (healthcare+education)	818	711	655
Research & graduate education	236	478	677
Mobility (passenger PT) & urban freight	141	129	108
Clothing / Laundry / Repair	441.2	320.6	245.1
Household goods & appliances	11.7	10.3	9.8
Capital goods & MRO	146.9	84.5	48.9
Materials & circular flows	65.1	61.6	73.6
Energy system buildout (CAPEX)	20.1	13.6	10.6
Freight & warehousing	122.8	92.0	67.7
Care services	1,106	946	849
Public space & facilities	141.1	95.5	67.2
Culture, libraries, media & knowledge commons	31.3	26.1	21.9
Environment & restoration	48.1	19.0	12.0
Disaster risk & civil protection	72.1	67.9	65.5
Administration & justice	13.55	8.44	5.99
Public governance stack	11.6	8.6	6.8
Standards, metrology & accreditation	12.8	11.8	11.1
Training & job guarantees (steady)	136.6	77.3	51.3
International coordination & trade	3.80	2.37	1.58
Waste & materials system	18.91	12.34	7.97
Animal & plant health	6.89	5.64	4.87
Sports & recreation	152.5	127.5	107.1
Hospitality	290.1	184.2	132.5
Retail	308.0	225.4	170.0
Personal services	455	326	244
Culture, arts, libraries & heritage	412.1	311.1	242.8
Tourism (visitor services)	48.4	40.0	31.8
Hobbies & makers	42.1	35.6	29.4
Media production	80.3	62.4	47.5
Pet services (non-clinical)	94.0	80.9	68.6
Grand total	21,150.1	7,252.7	5,393.6

From totals to a social workweek

Let H_s^{tot} be total weekly hours per 1,000 residents in scenario $s \in \{\text{Low}, \text{Med}, \text{High}\}$. Let L be working persons per 1,000 residents. The implied social workweek is

$$\tau_s(L) = \frac{H_s^{\text{tot}}}{L} \text{ hours/worker/week.}$$

Table 36.2: Illustrative social workweek $\tau_s(L)$ for selected labor force sizes L.

L (workers per 1,000)	Low	Medium	High
500	42.3	14.5	10.8
550	38.5	13.2	9.8
600	35.3	12.1	9.0

Why do we still work so much? A large share is socially unproductive

Much paid labor today preserves positions, paperwork, and pipelines rather than meeting needs. Democratic economic planning removes this load.

- **Guard labor**. Monitoring, compliance, corporate policing, and supervision scale with inequality and weak legitimacy, not with need [(356)]. Planning cuts duplication and rents.
- **Managerialism and "bullshit" jobs**. Whole layers exist to signal activity or manage images rather than deliver services [(357)]. Surveys repeatedly find that a third of workers say their job does not contribute meaningfully [(358), (359)].
- **Administrative burden**. Fragmented forms, permits, and reporting consume hours with little welfare gain; standardization and one-stop platforms reduce it [(360)].
- **Finance churn**. The unit cost of intermediation has not fallen over a century, implying large organizational slack [(361)]. Public rails and fee caps redirect talent to production.
- **Health system waste**. Overtreatment, pricing games, failures of care coordination, and excess admin are well documented [(362)]. Common records and global budgets shrink this category without cutting care.
- **Persuasive arms races**. Parts of advertising and related data work shift preferences without clear welfare gains; even when prices fall, total welfare can drop once search costs and manipulation are counted [(363), (364)].

Planning flips incentives: fix service floors first, then minimize necessary hours. Unproductive layers shrink by design. The time dividend becomes a right, not a byproduct.

General discussion

The totals in Table 36.1 show that a coordinated public system can meet floors with far fewer hours than current economies spend. Democratic economic planning is the method that converts those savings into time, security, and ecological compliance.

What planning changes in practice

1. Clear floors. Service levels are fixed in advance. Optimization does not chase profit. It meets floors at minimum necessary hours.

2. One platform per function. Food logistics, care records, asset maintenance, and payments run on shared public stacks. Duplication falls, interoperability rises.

3. Contact is protected. Human attention in care, teaching, libraries, and culture is scheduled first. Automation trims non contact overheads.

4. Design for long life. Procurement favors repairable goods, standard parts, and circular flows. Lifetime hours fall even if build hours are slightly higher.

5. Open coefficients. All models, data, and drivers are auditable. Anyone can propose changes. Accepted improvements cut hours for everyone.

Governance that keeps it democratic

- Budgets tie to floors. Votes set floors, not outputs. Operators report reliability and backlog. When floors are missed, labor is added before anything else.
- Open models and logs. Rosters, queues, and costs are reproducible. Citizens can run the numbers and challenge choices.
- Local choice inside common rails. Cities select menus and mixes, but share the same data formats, wage ladders, and safety protocols.
- Rotation and fair shifts. Unpleasant tasks are shared with seniority and health safeguards. No enclaves of permanent drudgery.

Transition path

1. Phase 1 stabilize floors. Fix staffing gaps in food, water, care, housing maintenance, and mobility. Merge duplicative back offices into the common stacks.

2. Phase 2 consolidate platforms. Migrate records, maintenance, and procurement to shared ledgers and catalogues. Adopt repairability standards and spares pools.

3. Phase 3 shorten the week. Reduce nominal hours in steps while holding floors. Reinvest time saved into training, retrofit, restoration, and culture.

Labor policy

- Job guarantees in foundational sectors with paid training pipelines.
- Right to predictable schedules and posted rosters.
- Portable benefits on the public platforms. No loss on sector moves.

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