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Setting targets for local energy planning: Critical assessment and a new approach

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ABSTRACT

Targets are crucial to the definition, effort and investment implied in any plan. The way how they are set should therefore be carefully thought and decided. In the context of local energy planning, however, the increasingly active attitude of local stakeholders has not yet been corresponded by an evolution on the way how targets are set. The aim of this work is to review how targets are currently defined and, after justification is found, to develop a new methodology for target setting in the context of local energy planning, that can guide local authorities and other stakeholders to act towards global climate change mitigation and other policy objectives.

This paper begins with a critical assessment of existing targets set in the context of local energy planning, in order to understand how they were defined and the implications of different methodological choices. Here, the drawbacks found on current practices call for the need of a new methodology that answers to two fundamental requisites: being able to reflect local characteristics and past accountability, by taking into account the starting point; and being quantitatively coherent with existing long-term goals. The paper then presents an alternative approach for target setting that corresponds to the referred requisites, and illustrates the implications through the application to nine municipalities in the Metropolitan Area of Porto.

1. Introduction

In the past few years, local authorities and communities have been gradually recognizing the importance of local climate and energy policies (OECD, 2008). Even though mostly prompted by the challenge of environmental sustainability, this awakening must also be seen as an aftermath of the growing concerns regarding the potential economic and social impacts deriving from the excessive use of energy products and services. More and more communities have become aware of the importance of energy in the local economy – not only by its negative impacts but also by the potential benefits it may bring (increasing the population well-being, jobs creation, boosting local economic activities) – prompting local stakeholders to have a more active role on climate change mitigation and, more specifically, on energy planning and management. A recent survey on local climate change actions showed that urban climate change experimentation has been a growing trend after the Kyoto ratification in 2005 and it is not confined to specific regions in the world (Broto & Bulkeley, 2013).

This increasingly active attitude by local stakeholders is perceived by academics as of extreme relevance to the achievement of climate change mitigation goals at global level. There are specific characteristics, as e.g. local authorities' competences and their role as energy users, that prompt local level as an appropriate level of action (Bulkeley & Betsill, 2005; Dodman, 2009). Indeed, local scale measures and policies can be as crucial as global scale actions for international objectives regarding climate change mitigation (Wang & Chen, 2013).

To contribute to climate change mitigation, the local energy action plans need nevertheless to be built on ambitious but rational targets. Targets are crucial to the successful outcome of any plan, as they guide and facilitate the monitoring process of its implementation and of the desired goal(s) achievement (Gupta et al., 2007). According to management literature, a target should be SMART—(S)pecific, (M)easurable, (A)chievable or (A)ccepted, (R)ealistic and (T)ime-bound (Edvardsson & Hansson, 2005). Additionally, taking into account the main goal of local energy planning and following the motto "Think globally, act locally", local targets

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should also reflect local accountability, i.e. the local contribution to global climate change mitigation (Huang & Lee, 2009).

The recent years have seen a rise of accountability indicators and methods, as e.g. through the quantification of local greenhouse gases (GHG) emissions per capita, prompted by the growing responsiveness of local actors (Neves & Leal, 2010). However, as will be shown in the work, this has not yet got a correspondent step-up in the way how targets are set in the context of local energy planning. In particular, it is often found that the same targets, in relative terms, are proposed for municipalities starting from very different situations. Also, the quantitative relationship between short-term targets and the long-term vision is often ignored or neglected. Indeed, a clear methodology leading to effective targets that echo global climate change mitigation goals is currently lacking. The aim of this work is then to review how targets are currently defined and then to develop a new methodology for target setting in the context of local energy planning, that can guide local authorities and other stakeholders to act towards global climate change mitigation objectives.

The paper is structured into four distinct sections. The first presents a review of target setting in the context of local energy action plans, through the analysis of seven examples representative of geographical and methodological diversity. It follows a section with the presentation of an alternative approach for target setting, focusing on the local accountability for global climate change mitigation. The third section includes the application of the new methodology proposed in the previous section to nine municipalities in the north region of Portugal, as well as a brief discussion on the results obtained. Finally, the fourth section presents the main conclusions derived from this work.

2. Target setting for local energy planning—a critical review

This section presents a review of existing targets established in the context of local energy planning, as a way to identify the main characterizing features and how they influence the targets' significance.

When selecting the case studies, the aim was to look over the diversity of methodologies for target setting in the context of local sustainability planning – not always specifically focused on energy planning – in order to identify the main characterizing features. As a result, this section presents the assessment of seven cases, comprising not only targets established at local level but also methodologies for local targets' calculation developed under higher level initiatives that promote climate change mitigation action at local level.

2.1. Covenant of Mayors

The Covenant of Mayors is an initiative promoted by the European Commission in order to foster sustainable energy planning at the local level and consequently contribute to the achievement of European Union GHG emissions reduction goal (CoM, 2010). The signatory cities commit to a voluntary agreement which includes the obligation of reducing their GHG emissions by at least 20% up to 2020, compared to the base year level. Despite the detailed technical and methodological guidance for local energy planning, the Covenant still allows participants to choose certain characteristics of their target, namely the scope, the unit and the base year to which the target is compared to.

2.2. Copenhagen

The goal of Copenhagen is to be the first carbon neutral capital in the World by 2025, which will be achieved by combining the reduction of its CO_2 emissions with the offset through electricity generation from renewable energy sources. Nevertheless, reducing CO_2 emissions is seen as the foremost solution and, by implementing the Climate Plan initiatives, the city intends to reduce its CO_2 emissions from 2.5 M t in 2005 to 1.15 M t by 2025 (City of Copenhagen, 2009). Additionally, an intermediate target of reducing local emissions by 20% between 2005 and 2015 was also set. Both targets refer to overall emissions, i.e. including all sectors of activity.

2.3. Freiburg

Freiburg is a pioneer city on climate change mitigation, being chosen in 1992 as Germany's Environment Capital. The first official resolution of acting locally towards the reduction of CO_2 emissions dates from 1996, when the city council resolved to cut by 25% Freiburg's CO_2 emissions by the year 2010. In 2007, following the monitoring of previous effort, a new target was set of reducing local emissions by 40% by 2030, compared to 1996 levels (City of Freiburg, 2011).

2.4. London

The Climate Change Mitigation and Energy Strategy, published in 2011, was presented as a strategic framework for enhancing London's quality of life and protecting the environment (Mayor of London, 2011). This strategy focuses on reducing local GHG emissions by 60% up to 2025, compared to 1990 levels, in order to guarantee that London is playing its part in tackling climate change. The target scope comprises emissions from Buildings (both Residential and Services) and Transport, being these responsible for a major share of local emissions. The Mayor has also set interim targets for 2015 and 2020, 20% and 40% emissions reduction respectively, in order to drive the scale of activity required to achieve the 2025 target.

2.5. Malmö

The Environmental Programme for the City of Malmö (City of Malmö, 2009) was adopted in 2009 by the City Council establishing general environmental objectives for the city, including more efficient energy consumption, more renewable energy, reduction of emissions, etc. In order to monitor all the objectives, different targets were set, being: (1) 40% reduction of overall GHG emissions by 2020, compared to 1990 levels; and (2) 20% reduction of energy consumption per capita, compared to average levels (2001–2005).

2.6. Stockholm

In 2010, the city of Stockholm had reduced carbon emissions by 25% per resident since 1990. Currently, the aim of local authorities is for the city to be fossil fuel-free by 2050, including all sectors of activity. This goal, as stated by the Climate Initiative, corresponds to cutting local emissions to 0 t of $CO_{2eq.}$ per capita per year (City of Stockholm, 2009). In order to guide action in medium-term, the city has set an intermediate target for 2015—to achieve 3 t of $CO_{2eq.}$ per capita per year, considering that in 2005 local emissions totalized about 4 t per capita.

2.7. Växjö

Although being a signatory of the Covenant of Mayors, the actions towards local sustainability started much earlier in the city of Växjö. The decision of becoming a fossil fuel free city dates from 1996 and since then targets have been periodically revised in order to guarantee the achievement of such goal. The most recent document – Energy Plan for the City of Växjö (City of Växjö, 2011) – establishes the targets for the period up to 2015, including: (1) 15%

reduction of final energy per capita between 2008 and 2015; and (2) 55% reduction of CO_2 emissions per capita by 2015, compared to 1993 levels.

Considering that a target should guide and motivate the implementation of the plans, it is important to evaluate characteristics as its measurability and the possibility to verify its achievement, as well as its alignment with the ambitioned goal(s) (Edvardsson Björnberg, 2013). Using the analysis of the presented cases and being inspired by the methodological considerations presented in Kramers et al. (2013), five features that may potentially influence such target characteristics were then identified, namely: (1) motivating goal; (2) target's object; (3) scope; (4) unit of the target; and (5) goal type. The intended meaning of each feature is explained in the following paragraphs.

Motivating goal refers to the objective behind the target, i.e. to what policy makers intend to achieve when developing the plan, being either local or at a higher geographical scale. There are infinite possibilities, ranging from better quality of life for local citizens to global climate change mitigation, and this was made clear when analyzing the presented cases. An additional message that was raised throughout the analysis was the blurred link between local targets and the overall goal of climate change mitigation. In the city of Malmö, for instance, the contribution of the local target to higher level objectives is not clearly mentioned. Though this does not imply that the setting of local targets does not consider higher level objectives, the consistency between the different local contributions and the achievement of climate change mitigation is not entirely ensured.

The **object** of the target is associated with what the target refers to, e.g. whether it sets an objective for the use of final energy, or the GHG emissions, or even to the amount of energy that is from renewable energy sources. As shown by the analysis, this is usually linked with the motivating goal of the plan; for instance, if the goal is to improve local energy efficiency the target is normally set in terms of final energy, while when aiming at climate change mitigation the use of GHG emissions could be more appropriate. In the case of Malmö and Vaxjö, for instance, the targets were set both in terms of final energy as in terms of emissions, as their goals comprised both the emissions and the improvement of local energy efficiency. All the other cases have only set targets in terms of emissions reduction, as their objectives were more focused on reducing the use of fossil fuels and/or on climate change mitigation. Despite justifiable in some cases by the different motivating goals, this diversity on object's choice hampers the comparability between targets.

The third feature – **scope** – is linked to the definition of the target boundaries. This includes not only the definition of the spatial boundaries but also the decision regarding which activities or sectors should be included in the target. In general, the geographical area covered by the targets is limited by the local geopolitical boundaries, i.e. it refers to the spatial area under the competence of local authorities. Concerning the sectors to be considered, there is a significant diversity though: while some of the targets presented concern all sectors of activity located within the local area (Copenhagen, Freiburg, Malmö, Stockholm and Växjö), London narrows the scope to the Buildings and Transport sectors. In the case of the Covenant of Mayors, the choice of the sectors to be comprised by the target is somehow left to the local authorities, as they can choose to include Industry and/or Agriculture as long as local actions within these sectors are included in the local energy plan.

The **unit** of the target refers to how the object of the target should be evaluated, either for the city as a whole (absolute) or normalized to a socioeconomic indicator, e.g. per person or per unit of GDP. Within the cases presented, there are a few that set the target for the whole city—neglecting potential changes in the socioeconomic variables, while others consider the demographic evolution by setting the targets per person. The latter, besides allowing for the consideration of potential demographic changes, also improves the comparability of the targets of different municipalities.

The **goal type** refers to the decision on whether to define an absolute target or setting it as a change in relation to a previous/current state. For instance, to achieve a certain level of GHG emissions corresponds to an absolute target, while to achieve a reduction of a percentage in regard to a base year is a relative one. As seen by the targets presented, the option of a relative target implies the selection of a reference state to which to compare to, what could be misleading. Indeed, considering the case of the Covenant of Mayors, the fact that the 20% reduction of GHG emissions is measured against a base year "punishes" the municipalities that currently (or in a recent past) already have a low level of emissions—due to previous effort or to local characteristics of economic development or inherent to the energy system.

A summary of the targets setting analysis following the framework above, i.e. regarding the five features discussed in this section, is presented in Table 1. Overall, a fundamental message prompted by the analysis is the substantial diversity of ways of setting and expressing the targets. This in itself may be an obstacle to a clear comparison of local climate and energy targets and, potentially, of local actions—as their achievements are commonly assessed by measuring the verified state versus the target. As recognized along the review, the lack of comparability between the different case studies is justified by the absence of a common framework, as the presented approaches were developed at different moments in time and prompt by different goals. Even though, and considering the increasingly globalized world we are in, to ensure the comparability of local targets from now on could have significant benefits (as, for instance, to facilitate the transfer of good practices).

Moreover, there are also some critical issues posed by the current practices that go much beyond the mere signaling of the diversity of methods. On one hand, there is the fact that some of the methodologies presented set the emissions reduction targets as a percentage of the current state, disregarding whether this state is far (or not) from local policy objectives. The targets set using this approach do not echo local accountability, as they "punish" municipalities with starting low levels of emissions. On the other hand, it is strikingly noticeable the absence of a clear correlation between short or medium-term local targets and long-term objectives, expressed in absolute terms. This is pivotal in the sense that this omission of a quantifiable link with long-term targets could endanger the achievement of the latter.

3. An alternative approach for local target setting

As previously stated, the aim of this work is to establish a new methodology for target setting, that is in line with the long term-goals[1] of global climate change mitigation and that accounts for the particular circumstances of each municipality regarding their current situation, size and main activities. A proposal of such methodology is described in this section, including the explanation of the rationale behind it and the main assumptions considered. A short list of the nomenclature used along this section is presented below.

Target $_{Energy2050}$—Target for GHG emissions related with energy uses for 2050 (tonnes of $CO_{2eq.}$ per capita)

Share $_{Non\text{-}Energy2050}$—Projected share of GHG emissions associated with non-energy uses compared to the overall GHG emissions for 2050 (dimensionless quantity, between 0 and 1)

[1] Within this paper, the terminology adopted to characterize different time horizons complies with the following: short-term refers to a time horizon of about 5 years; medium-term refers to a horizon of about 20 years; and long-term to a horizon longer than 30 years.

Table 1
Analysis of the chosen targets according to their characterizing features.

	Target description	Motivating goal	Object	Scope	Unit	Absolute vs. Relative
Covenant of Mayors	At least 20% reduction of GHG emissions, compared to base year	EU climate and energy targets	GHG emissions	Buildings, Transport and Public lighting (mandatory) Others (when improvement measures are considered)	Total or per capita	Relative to base year
Copenhagen	Reduction of 1.2 M t of CO_2 emissions	Carbon neutral by 2025	CO_2 emissions	All sectors	Total	Relative to a base year
Freiburg	40% reduction of CO_2 emissions by 2030, compared with 2007 levels	Climate change mitigation	CO_2 emissions	All sectors	Total	Relative to a base year
London	60% reduction of CO_2 emissions by 2025, compared to 1990 levels	Climate change mitigation	GHG emissions	Buildings and Transport	Total	Relative to a base year
Mälmö	At least 40% reduction of GHG emissions, compared to base year		GHG emissions	All sectors	Total	Relative to a base year
	At least 20% reduction of energy consumption (final energy) per person	Increase energy efficiency	Final energy	All sectors	Per capita	Relative to a base year
Stockholm	Reduce GHG emissions to 3 $tCO_{2eq.}$ per capita by 2015	Carbon neutral by 2050	GHG emissions	All sectors	Per capita	Absolute
Växjö	15% reduction of energy consumption per person between 2008 and 2015	Efficient use of energy	Final energy	All sectors	Per capita	Relative to a base year
	55% reduction of CO_2 emissions per person (associated with the use of fossil fuels) between 1993 and 2015	Cease the use of fossil fuels	CO_2 emissions	All sectors	Per capita	Relative to a base year

Target $_{B+T2050}$—Target for GHG emissions associated with the energy use in buildings (both residential and services), transport and public lighting for 2050 (tonnes of $CO_{2eq.}$ per capita)

Share $_{I+AF2050}$—Projected share of GHG emissions associated with the energy use in the Industry and the Agriculture and Fisheries sectors compared to the overall GHG emissions associated to energy uses for 2050 (dimensionless quantity, between 0 and 1).

GHG $_{B+TBaseyear}$—GHG emissions associated with the energy use for buildings, transport and public lighting for the base year in the studied municipality (tonnes of $CO_{2eq.}$ per capita)

Base Year—First year of the time horizon considered for the planning exercise (years)

Horizon—Last year of the time horizon considered for the planning exercise (years, between the base year and 2050)

3.1. Absolute long-term target

As estimated by the *Intergovernmental Pannel on Climate Change* (IPCC), in order to avoid catastrophic climate change, the temperature increase should not exceed the 2 °C (World average), what requires limiting the concentration of greenhouse gas (GHG) emissions in the atmosphere to 450 ppm (parts per million) (IPCC, 2007). Not overpassing this concentration implies GHG emissions reductions of about 60% compared to 2010 levels, reaching a level of 20 $GtCO_{2eq.}$ per year.[2] According to recent demographic forecasts that project that World's population will reach 9.3 billion habitants by 2050 (IPCC, 2014), this ceiling corresponds to reducing the World's greenhouse gas emissions to the level of 2 t of $CO_{2eq.}$ per capita (tpc) per year, by the year 2050. In 2010, the average level of GHG emissions in the World was around 4.9 t of $CO_{2eq.}$ per capita per year, while the equivalent for the European Union (EU) was about 7.4 (OECD, 2012).

Being the reduction of GHG emissions a global common, i.e. non-rival and non-excludable, everyone benefits from actions towards climate change mitigation even they do not contribute any effort themselves, and independently of the administrative level at which they are implemented. Local actions are not an exception. Thus, while contributing to global problem, local climate change mitigation actions and the respective targets should be coherent and reflect the global objectives. In consequence, in order to align local target setting with climate change mitigation at the global level, the methodology proposed here takes as the motivating long-term target the achievement of 2tpc per year by 2050. Nonetheless, it is important to notice that the structural point here is the definition of a common long-term target that is scientifically-based and that reflects the existing global objectives towards climate change mitigation. Then, if the target of achieving the 2tcp per year is revised by the scientific community, the common long-term target for local actions should be changed accordingly.

Moreover, it is worth noticing that this decision does not necessarily imply that a 2 t of $CO_{2eq.}$ per capita per year target should be set for the plans of every municipality. On the one hand, this figure refers to overall GHG emissions, including emissions that are not associated with energy use; on the other, the World's average may not be directly applicable to smaller scales due to the accountability of GHG emissions associated to supra-local services and activities.

[2] The majority of scenarios reaching this atmospheric concentration level are associated with GHG emissions reductions of over 40% to 70% by 2050 compared to 2010 levels, corresponding to a reduction of overall GHG emissions to a level of 15–29 $GtCO_{2eq.}$ per year (The World Bank, 2014).

Thus, the methodology for target setting proposed by this work, although based on the overall goal of reaching 2tpc, is then adjusted to the context of local energy planning by considering these issues, as will be presented in the following sections.

3.2. Discounting non-energy related emissions

As previously said, the goal of 2 t of $CO_{2eq.}$ per capita per year by 2050 refers to overall GHG emissions, including emissions associated with non-energy uses. Considering that the aim of this work is to facilitate target setting in the context of local energy planning, the methodology should only take into account the emissions associated with energy uses. As such, it is necessary to discount non-energy use emissions from the overall emissions goal, setting a target for the emissions associated with energy uses.

The emissions associated with non-energy uses are mostly subsequent from agriculture, livestock and land use, being then linked to activities that serve the whole population indiscriminately. Consequently, and considering also the difficulty of establishing an individual accountability for every inhabitant or locality, it is assumed as reasonable that the emissions associated to those activities are evenly distributed within a larger geographical area (country or region, depending on the scope of the analysis). This assumption infers that the target for GHG emissions related solely with energy use can be estimated by subtracting the predicted share of non-energy use emissions by 2050 to the overall goal of 2tpc (Eq. (1)). The share attributed to non-energy uses emissions may depend on the geographical area, as the weight of the related activities may differ significantly depending on the country or region considered.

$$\boldsymbol{Target}_{\boldsymbol{Energy}2050} = 2\boldsymbol{tpc} \times \left(1 - \boldsymbol{Share}_{\boldsymbol{Non-Energy}2050}\right) \quad (1)$$

3.3. Discounting ghg emissions associated with supra-local services

Given the time horizon of the GHG emissions goal, it is assumed reasonable to transpose the global objective of energy use emissions *quid pro quo* to smaller scales, as to the regional level (as the EU, e.g.) and even to the national level. However, the same does not apply when transferring the objective to local level, due to the accountability of emissions from supra-local services. Indeed, part of the emissions included in the inventory of a municipality are associated with activities that serve an area that exceeds the municipal borders, serving also neighboring municipalities, the whole country or even beyond national borders. Accordingly, and considering that these emissions may comprise a large share of the local emissions, the transfer of goods between municipalities associated with such activities should be considered in order to adequate the local contribution to the emissions accountable to its own inhabitants.

Considering the information available, identifying the transfer of goods and services across municipalities might be extremely challenging, as the data is not sufficient to provide an estimation with acceptable levels of uncertainty. Also, taking into account that these transfers are mostly associated with activities in the Industry and Agriculture & Fisheries sectors, the political competences of local authorities over these transfers are usually limited. Hence, it is assumed to be pertinent to discount the emissions associated with supra-local activities – namely from Industry and Agriculture & Fisheries – from the global target for GHG emissions associated with energy use, in order to set local targets for energy planning. Contrarily, for the Services sector, it is assumed that the associated emissions must be considered in the definition of local targets, even if the related activities may also circulate across municipalities. Indeed, not only the transfer of services is of significantly lower dimension than for the Industry and Agriculture & Fisheries sectors but also, considering that the energy use associated with the Services sector corresponds to the energy use in services' buildings, local authorities have strong political competences over the associated emissions.

In the aforementioned context, this methodological choice is advantageous in the sense that it does not consider as local a large share of the emissions that despite emitted in the municipality are not associated with the use of energy by local citizens. Besides, this approach also restrains the scope to local geopolitical boundaries, excluding activities that are usually outside of the scope of local authorities' competences.

The proposed approach for discounting emissions associated with supra-local services follows a similar rationale to the suggested above for discounting emissions associated with non-energy uses, i.e. it consists in assuming that the emissions associated with the sectors of Industry and Agriculture & Fisheries are approximately evenly distributed by different municipalities, proportionally to the local population. Thus, the local target for GHG emissions associated with the Buildings and Transport sectors for 2050 can be obtained by subtracting the national or regional share of emissions associated with the Industry and Agriculture & Fisheries sectors to the target set for all energy uses (Eqs. (2) and (3)). As above, here the share may vary according to the geographical area considered, as the weight of the Industry and Agriculture & Fisheries sectors may be very different between regions or countries.

$$\boldsymbol{Target}_{\boldsymbol{B+T}2050} = \boldsymbol{Target}_{\boldsymbol{Energy}2050} \times \left(1 - \boldsymbol{Share}_{\boldsymbol{I+AF}2050}\right) \quad (2)$$

or

$$\boldsymbol{Target}_{\boldsymbol{B+T}2050} = 2\boldsymbol{tpc} \times \left(1 - \boldsymbol{Share}_{\boldsymbol{Non-Energy}2050}\right) \times \left(1 - \boldsymbol{Share}_{\boldsymbol{I+AF}2050}\right) \quad (3)$$

3.4. Time frame of local energy planning: medium term

Despite the importance of being built over long-term objectives, local energy plans usually aim at short or medium terms. Thus, it was shown to be necessary to propose a methodology to set intermediate targets, starting (back casting) from the long-term targets (calculated as suggested above). This section illustrates this process.

Having set the local targets for 2050 for the Buildings and Transport sectors, it seems appropriate to consider the current (or past) GHG emissions as the starting point, and the long-term target as the end goal. This rationale is assumed in order to consider the current/past situation (which can be influenced by past actions), while ensuring the achievement of long-term objectives. Given the high level of uncertainty regarding the optimal path towards the reduction of GHG emission up to 2050, the evolution between the base situation and the 2050 target is assumed as linear for target-setting purposes (Fig. 1).

As a result, the setting of intermediate targets can be done by identifying the level of GHG emissions that corresponds to the time horizon of the plan in the straight line drawn between the base situation and the local target set for 2050. Eq. (4) comprises the mathematical expression that describes this procedure.

$$\text{Target}_{\boldsymbol{B+THorizon}} = \boldsymbol{GHG}_{\boldsymbol{B+TBaseyear}} + \frac{\text{Target}_{\boldsymbol{B+T}2050} - \boldsymbol{GHG}_{\boldsymbol{B+TBaseyear}}}{2050 - Baseyear} \times (\boldsymbol{H}orizon - Baseyear) \quad (4)$$

While seemingly simple, this procedure is remarkably different from all the procedures that were found in the review presented

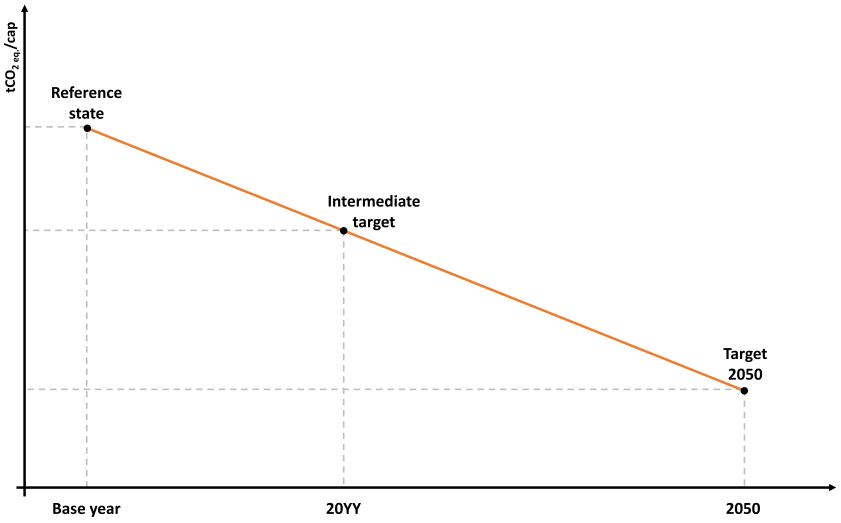

Fig. 1. Scheme illustrating the rationale to set local intermediate targets.

Table 2
Review of the share of GHG emissions associated with energy use by the Buildings and Transport sectors.

Study/Report	Geographical scope	Time horizon	Share of "Buildings + Transport"	
			Base year	Horizon
RNBC (APA, 2012)	Portugal	2009–2050	62%	27–38%
Transport and Energy Trends (EC, 2010)	EU 27	2010–2050	76%	76%
2050 Roadmap (EC, 2011)	EU 27	2005–2050	70%	68–70%
Energy [R]evolution (Greenpeace, 2010)	OECD Europe	2007–2050	66%	72%
Energy Technologies Perspective (IEA, 2010)	OECD Europe	2007–2050	67%	76%

in the Section 2. Indeed, despite its simplicity, it does answer to the two fundamental objectives established for the new approach: (1) being able to take into account the starting point; and (2) being quantitatively coherent with existing long-term goals. Finally, it is important to notice that the assumption of a linear progression towards the GHG emissions target up to 2050 was a way to cope with the uncertainty as well as the subjectivity of what is the optimal path towards the long-term target. However, this could be replaced by a convex or concave curve according to local specificities, as long as the decision makers agree to do so. Indeed, the structural aspect of the proposed methodology it is the existence of a projection line between the current/past situation and the long-term target, and not its shape.

4. Application to nine municipalities in the metropolitan area of Porto

This section includes the application of the proposed methodology to set the targets of nine municipalities in the northern region of Portugal—more specifically, in the Metropolitan Area of Porto. The chosen municipalities are diverse, both in terms of the weight of economic activities and in terms of verified level of GHG emissions.

4.1. Common target for 2050

Setting the local targets for 2050 comprised three steps: (1) establishing a global GHG emissions reference for 2050; (2) discounting of non-energy use related emissions; and (3) discounting of emissions associated with supra-local services.

The global target for 2050 considering all emissions was 2 t of $CO_{2eq.}$ per capita, as in Section 3.1. Then, in order to discount the emissions associated with non-energy uses, it was necessary to assume a value for the share of these on the overall level of emissions. Despite the numerous documents, both at the national and international level, presenting GHG emissions estimates up to 2050, there are not many that distinguish between the emissions associated with energy use and with non-energy use. Therefore, based on historic values as well as on the predictions presented for Portugal by (APA, 2012),[3] it was assumed that the GHG emissions associated with non-energy use would represent about a quarter (25%) of the overall emissions by 2050. The overall target for GHG emissions associated with energy uses for 2050 was then established as 1.5 t of $CO_{2eq.}$ per capita per year.

Regarding the discount of emissions associated with supra-local services, the share allocated to the Industry and Agriculture & Fisheries was established based on several studies that present both the current/recent share as well as its projection up to 2050 (APA, 2012; Greenpeace, 2010; EC, 2011, 2013; IEA, 2010). The values presented by the analysed studies are introduced in Table 2. Furthermore, as proposed in the previous section, the products' consumption associated with the discounted emissions are considered to be homogenously distributed within the country, on a per capita basis, which implies a common target for Buildings and Transport for 2050 for all Portuguese municipalities. Based on the figures presented in Table 2, it was decided to reserve a quota for the GHG

[3] The projections presented by APA (2012) for Portugal, indicate that the GHG emissions associated with non-energy uses would lie between 24% and 29% of the overall emissions by 2050, considering the scenario with lower economic development. Currently, the GHG emissions associated with non-energy uses in Portugal correspond to about 15% of the overall emissions. For these estimations, the authors of the referred report have considered the emissions associated with: livestock production (animals' enteric fermentation and manure management); rice plantations; and other agricultural activities (soils and agricultural residues).

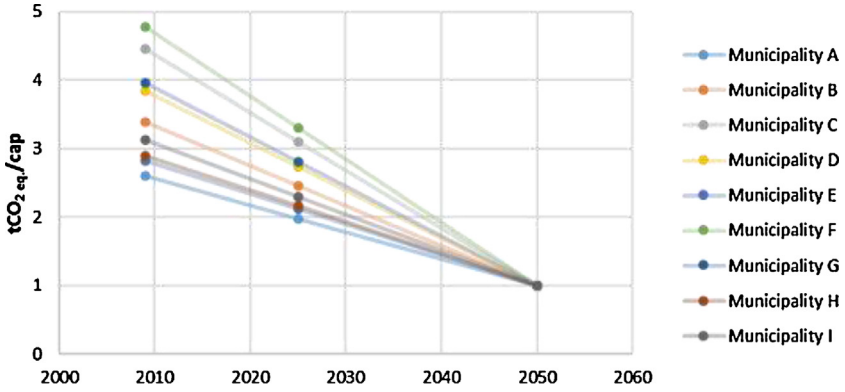

Fig. 2. Graphic representation of the method to establish differentiated targets for 2025 for the nine municipalities.

Table 3
GHG emissions targets established for nine municipalities in the northern region of Portugal, according to the methodology proposed in this paper.

	GHG emissions per capita ($tCO_{2eq.}$)[a]		GHG emissions' reduction compared to 2009 level
	2009	2025 Target	
Municipality A	2.60	1.98	24.0%
Municipality B	3.40	2.46	27.5%
Municipality C	4.45	3.10	30.3%
Municipality D	3.84	2.73	28.9%
Municipality E	2.83	2.11	25.2%
Municipality F	4.78	3.30	30.9%
Municipality G	3.96	2.80	29.2%
Municipality H	2.90	2.16	25.5%
Municipality I	3.13	2.30	26.6%

[a] Including the GHG emissions associated with the energy use in Buildings, Transport and Public Lighting (street lighting and traffic lights).

emissions associated to Industry and Agriculture & Fisheries corresponding to about one third of the energy use emissions, thus resulting in reserving 0.5tpc for the sectors of Industry and Agriculture & Fisheries. Accordingly, a local target of 1 t of $CO_{2eq.}$ per capita per year by 2050 was established for the level of GHG emissions associated with the energy use in the Buildings and Transport sectors for all municipalities in Portugal.

As a result, applying the approach proposed by this work to nine municipalities in the Metropolitan Area of Porto establishes a common target for local energy planning of 1 t of $CO_{2eq.}$ per capita per year by 2050, which is coherent with the achievement of the overall target of 2 t per capita while accounting solely for the GHG emissions derived from energy use by local population within geopolitical boundaries.

4.2. Specific targets for 2025

Considering the fact that 2020 is already too close (given the nature of the problem and actions required) but that medium-term is advised as the adequate time frame for local energy planning, the local targets were set for 2025. As proposed in the previous section, the intermediate target for each municipality was calculated having a verified state as the starting point and the common target for 2050 as the ultimate goal, and considering a linear path (Fig. 2). The base year is 2009, given the recent publication of the 2009 energy matrices for all nine municipalities (Leal, Santos, Mourão, & Souza, 2012).

Table 3 presents the local targets obtained for GHG emissions for the Buildings and Transport sectors for the nine municipalities, in absolute terms, and the required emissions reduction compared to 2009 level. It is noteworthy the observed relationship between the verified state and the required reduction; i.e. the lower the 2009 level of GHG emissions, the lower the required reduction and vice-versa. This correlation illustrates how the proposed methodology accounts for the initial state, e.g. rewarding municipalities that had favorable intrinsic conditions or previous efforts, unlike other mainstream methodologies.

Additionally, it is interesting to notice that all targets exceed the 20% bar, which is required from the signatories of the Covenant of Mayors. However, as the timeframe of this approach (2025) is not equal to the Covenant's, the targets set here cannot be seen necessarily as more ambitious than the one required by the initiative.

5. Conclusions

The review of the targets in the context of local energy planning has shown a lack of standardization on the different methodologies used to define and to express them, leading to a diversity that may not only hamper the comparison between different municipalities' actions but also prevent a consistent assessment of their global impact. More importantly, it was also found that certain common choices regarding targets' features (e.g. a% target) can ignore or account insufficiently for the initial state and/or early efforts of local authorities and can lead to a misalignment between medium and long-term targets.

Thus, considering the issues raised by the targets' review, this work proposes a new methodology for setting targets, to be used by municipalities or other "local" entities, that ensures the alignment between short/medium-term and long-term targets regarding global climate change mitigation. The rationale behind it is to define a global long-term target (e.g. 2 t of $CO_{2eq.}$ per capita by 2050) and then, adjust it in order to: (1) discount GHG emissions associated with non-energy uses; and (2) discount GHG emissions associated with supra-local services. The final step is to compute the intermediate/medium-term target by interpolating between the present situation and the long-term target, as described in Eq. (4). Despite seemingly simple, this methodology does comply with the two fundamental requisites established for the new approach:

being able to take into account the starting point; and being quantitatively coherent with existing long-term goals.

When applying this methodology to nine municipalities in the Metropolitan Area of Porto (Portugal), to establish targets for 2025, the results showed that the reductions needed for all municipalities in order to be aligned with the global target of 2 tpc by 2050 vary between 24.0% and 30.9%. This range of 6.9% is significant within the context and validates the relevance of the methodology, which would nevertheless be justified solely by ensuring coherence between medium and long-term targets.

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References

Agência Portuguesa do Ambiente (APA), Comité Executivo da Comissão para as Alterações Climáticas, 2012. Roteiro Nacional de Baixo Carbono—Análise Técnica das Opções de Transição para uma Economia de Baixo Carbono Competitiva em2050. Agência Portuguesa do Ambiente.

Broto, V. C., & Bulkeley, H. (2013). A survey of urban climate change experiments in 100 cities. *Global Environmental Change*, *23*(1), 92–102.

Bulkeley, H., & Betsill, M. (2005). Rethinking sustainable cities: multilevel governance and the 'Urban' politics of climate change. *Environmental Politics*, *14*(1), 42–63.

City of Copenhagen. (2009). *Copenhagen climate plan—the short version. Copenhagen carbon neutral by 2025*. City of Copenhagen: Technical and Environmental Administration.

City of Freiburg. (2011). *Green City Freiburg. Freiburg Wirtschaft Touristik und Messe*. GmbH & Co. KG.

City of Malmö. (2009). *Environmental programme for the City of Malmö 2009–2020*. City of Malmö: Environmental Department.

City of Stockholm, 2009. The City of Stockholm's Climate Initiatives.

City of Växjö, 2011. Energy plan for the City of Växjö.

Covenant of Mayors (CoM), 2010. How to Develop a Sustainable Energy Action Plan (SEAP)—Guidebook. Publications Office of the European Union, 2010 © European Union, Luxembourg, 2010.

Dodman, D. (2009). Blaming cities for climate change?: An analysis of urban greenhouse gas emissions inventories. *Environment and Urbanization*, *21*, 185–201.

Edvardsson, K., & Hansson, S. O. (2005). When is a goal rational? *Social Choice and Welfare*, *24*, 343–361.

Edvardsson Björnberg, K. (2013). Rational climate mitigation goals. *Energy Policy*, *56*, 285–292.

European Commission (EC), 2010. Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG. EU energy trends to 2030 - Update 2009.

European Commission (EC), 2011. Commission Staff Working Paper–Impact Assessment—Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions—Energy Roadmap 2050. SEC (2011) 1565.

European Commission (EC), 2013. EU Energy, Transport and GHG Emissions Trends to 2050-Reference Scenario 2013. Directorate-General for Energy, Directorate-General for Climate Action and Directorate-General for Mobility and Transport. ISBN: 978-92-79-33728-4.

Greenpeace, 2010. Energy [R]evolution—towards a fully renewable energy supply in the EU 27.

Gupta, S., Tirpak, D. A., Burger, N., Gupta, J., Höhne, N., Boncheva, A. I., et al. (2007). Policies, instruments and co-operative arrangements. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds.), *Climate change 2007: mitigation. contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change* (pp. 745–807). Cambridge and New York: Cambridge University Press.

Huang, W. M., & Lee, G. W. M. (2009). Feasibility analysis of GHG reduction target: lessons from Taiwan's energy policy. *Renewable and Sustainable Energy Reviews*, *13*, 2621–2628.

Intergovernmental Pannel on Climate Change (IPCC), 2007. Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Pannel of Climate Change, December 2007.

Intergovernmental Pannel on Climate Change (IPCC), 2014. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Pannel of Climate Change, April2014. Final Draft.

International Energy Agency (IEA). (2010). *Energy Technologies perspectives 2010—scenarios and strategies to 2050*. OECD/IEA.

Kramers, A., Wangel, J., Johansson, S., Höjer, M., Finnveden, G., & Brandt, N. (2013). Towards a comprehensive system of methodological considerations for cities' climate targets. *Energy Policy*, *62*, 1276–1287.

Leal, V., Santos, H., Mourão, Z., & Souza, G. (2012). *Matriz energética dos concelhos da Área metropolitana do porto na margem norte do rio douro*. Fundação Gomes Teixeira, Universidade do Porto.

Mayor of London. (2011). *Delivering London's energy future: the Mayor's climate change mitigation and energy strategy*. Greater London Authority.

Neves, A. R., & Leal, V. (2010). Energy sustainability indicators for local energy planning: review of current practices and derivation of a new framework. *Renewable and Sustainable Energy Reviews*, *14*, 2723–2735.

OECD. (2008). Competitive cities and climate change. In *OECD conference proceedings, Milan*.

OECD. (2012). *OECD environmental outlook to 2050: the consequences of inaction*. OECD Publishing.

The World Bank. (2014). *The World Bank Data: CO*.. July, 2014. http://data.worldbank.org/indicator/EN.ATM.CO2E.PC

Wang, Q., & Chen, X. (2013). Rethinking and reshaping the climate policy: literature review and proposed guidelines. *Renewable and Sustainable Energy Reviews*, *21*, 469–477.