

# Sustainable Energy Innovation: Kosovo and The Clean Energy Transition

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# Clean Energy Transition Research Agenda

1. Replacing aging infrastructure – Kosovo
2. Energy storage – game-changing technology?
3. Sustainable, Healthy, and Resilient Transition



# Technology Cost and Performance

nature  
energy

ARTICLES

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## Energy storage deployment and innovation for the clean energy transition

Noah Kittner<sup>1,2</sup>, Felix Lill<sup>2,3</sup> and Daniel M. Kammen<sup>1,2,4\*</sup>

Bulletin  
of the  
Atomic  
Scientists

### A battery of innovative choices—if we commit to investing

Noah Kittner and Daniel M. Kammen

#### ABSTRACT

Renewable energy – such as photovoltaics and wind power – is rapidly moving into the mainstream, with global solar capacity set to outproduce nuclear energy capacity for the first time. But a major holdup has been how to store the electricity produced by renewables; consequently, good, cheap, long-lasting battery storage has been the Holy Grail of R&D in this area. But how close are we in reaching this goal? To track progress, the authors have introduced a new, “two-factor” model of analyzing innovations in energy storage that accounts not only for total sales of a particular technology but also for the degree of investment in innovation, measured by looking at the number of new patents issued in energy storage technology.

#### KEYWORDS

Batteries; energy storage; renewables; R&D; innovation

RENEWABLES 2017  
GLOBAL STATUS REPORT



# Sustainable Energy Modeling

IOP Publishing

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Environmental Research Letters



LETTER

## An analytic framework to assess future electricity options in Kosovo

OPEN ACCESS

Noah Kittner<sup>1,2</sup>, Hilda Dimco<sup>3</sup>, Visar Azemi<sup>3</sup>, Evgenia Tairyana<sup>3</sup> and Daniel M Kammen<sup>1,2,4</sup>

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**Keywords:** electricity supply and demand, Kosovo, coal financing, sustainable electricity, electricity pathways, South East Europe, economies in transition

Supplementary material for this article is available [online](#)

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ELSEVIER

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Biomass and Bioenergy

journal homepage: <http://www.elsevier.com/locate/biombioe>



Research paper

## Deforestation and biomass fuel dynamics in Uganda

Pamela Jagger<sup>a,\*</sup>, Noah Kittner<sup>b</sup>




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<sup>b</sup> Energy and Resources Group, University of California, Berkeley, 310 Barrows Hall, Berkeley, CA 94720-3050, USA

# Life Cycle Assessment

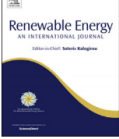
# Environment, Health, & Resilience

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Renewable Energy


journal homepage: [www.elsevier.com/locate/renene](http://www.elsevier.com/locate/renene)




Energy return on investment (EROI) of mini-hydro and solar PV systems designed for a mini-grid

Noah Kittner <sup>a, b</sup>, Shabbir H. Gheewala <sup>c, d, e, \*</sup>, Daniel M. Kammen <sup>a, b, f</sup>

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<sup>d</sup> Centre of Excellence on Energy Technology and Environment, PERDO, Bangkok, Thailand  
<sup>e</sup> Department of Environmental Sciences and Engineering, Gillings School of Public Health, University of North Carolina, Chapel Hill, NC 27514, United States  
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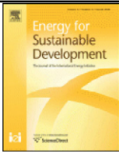

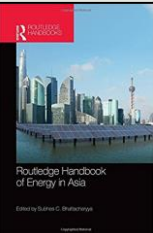


Energy for Sustainable Development

An environmental life cycle comparison of single-crystalline and amorphous-silicon thin-film photovoltaic systems in Thailand

Noah Kittner <sup>a</sup>, Shabbir H. Gheewala <sup>b, c, \*</sup>, Richard M. Kamens <sup>a, d</sup>

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<sup>d</sup> Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, NC 27599, USA

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COSTS AND BENEFITS OF BIOFUELS IN ASIA

Shabbir H. Gheewala, Noah Kittner, and Xunpeng Shi

ENVIRONMENTAL Science & Technology

Article


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[pubs.acs.org/est](http://pubs.acs.org/est)

Trace Metal Content of Coal Exacerbates Air-Pollution-Related Health Risks: The Case of Lignite Coal in Kosovo

Noah Kittner, <sup>†,‡,§,●</sup> Raj P. Fadadu, <sup>§</sup> Heather L. Buckley, <sup>§,‡,●</sup> Megan R. Schwarzman, <sup>§,||</sup> and Daniel M. Kammen <sup>\*,†,‡,⊥</sup>

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Energy Policy

journal homepage: [www.elsevier.com/locate/enpol](http://www.elsevier.com/locate/enpol)

Energy security in ASEAN: A quantitative approach for sustainable energy policy

Sopitsuda Tongsopt <sup>a,\*</sup>, Noah Kittner <sup>b</sup>, Youngho Chang <sup>c</sup>, Apinya Aksornkij <sup>a</sup>, Weerin Wangjiraniran <sup>a</sup>

<sup>a</sup> Energy Research Institute, Chulalongkorn University, Thailand  
<sup>b</sup> Energy and Resources Group, University of California Berkeley, USA  
<sup>c</sup> Division of Economics, Nanyang Technological University, Singapore

Noah Kittner and Kensuke Yamaguchi

Hydropower threatens peace in Myanmar -  
- but it doesn't have to

NIKKEI ASIAN REVIEW

Dialogue, transparency and foreign support could help rebuild local trust



BERKELEY CENTER FOR GREEN CHEMISTRY

FULBRIGHT



KOSID

KOSOVO CIVIL SOCIETY CONSORTIUM FOR SUSTAINABLE DEVELOPMENT

KONSORCIUMI KOSOVAR I SHOQËRISË CIVILE PËR ZHVILLIM TË QËNDRUESHËM



Rockefeller Brothers Fund

Philanthropy for an Interdependent World



Renewable & Appropriate Energy Laboratory

RAEL



USAID FROM THE AMERICAN PEOPLE



Forest Use • Energy • Livelihoods

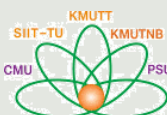


DEVELOPMENT IMPACT LAB



LMPPPI

Lower Mekong Public Policy Initiative



JGSEE

The Joint graduate School of Energy and Environment

Anthropocene Institute



SEE CHANGE NET FOUNDATION



British Embassy Bangkok



ENERGY RESEARCH INSTITUTE



Department of Alternative Energy Development and Efficiency  
MINISTRY OF ENERGY



INSTITUTE FOR THE ENVIRONMENT



東京大学 THE UNIVERSITY OF TOKYO



東京大学政策ビジョン研究センター Policy Alternatives Research Institute

RAEL

Renewable & Appropriate Energy Laboratory Professor Daniel Kammen, UC Berkeley

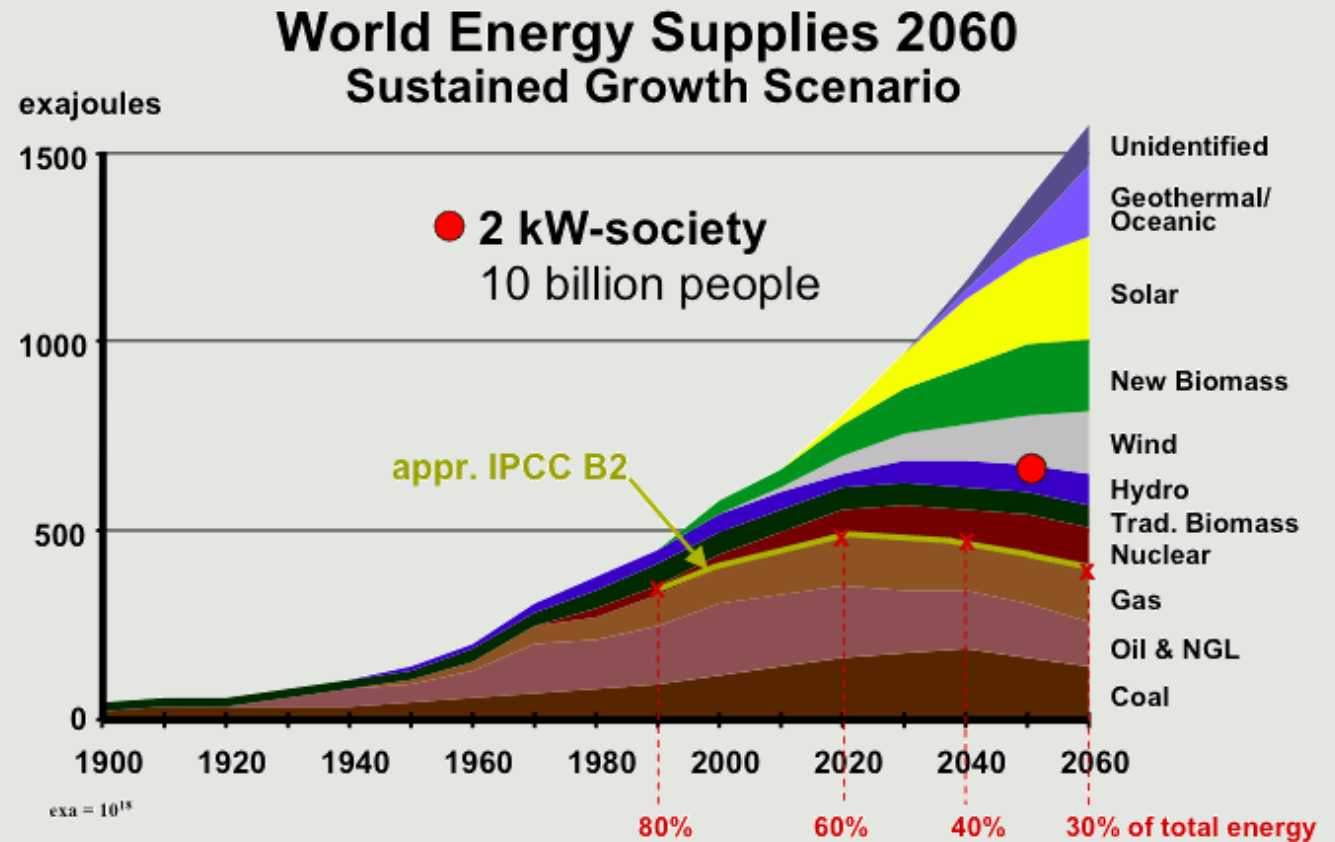


Economic Research Institute for ASEAN and East Asia

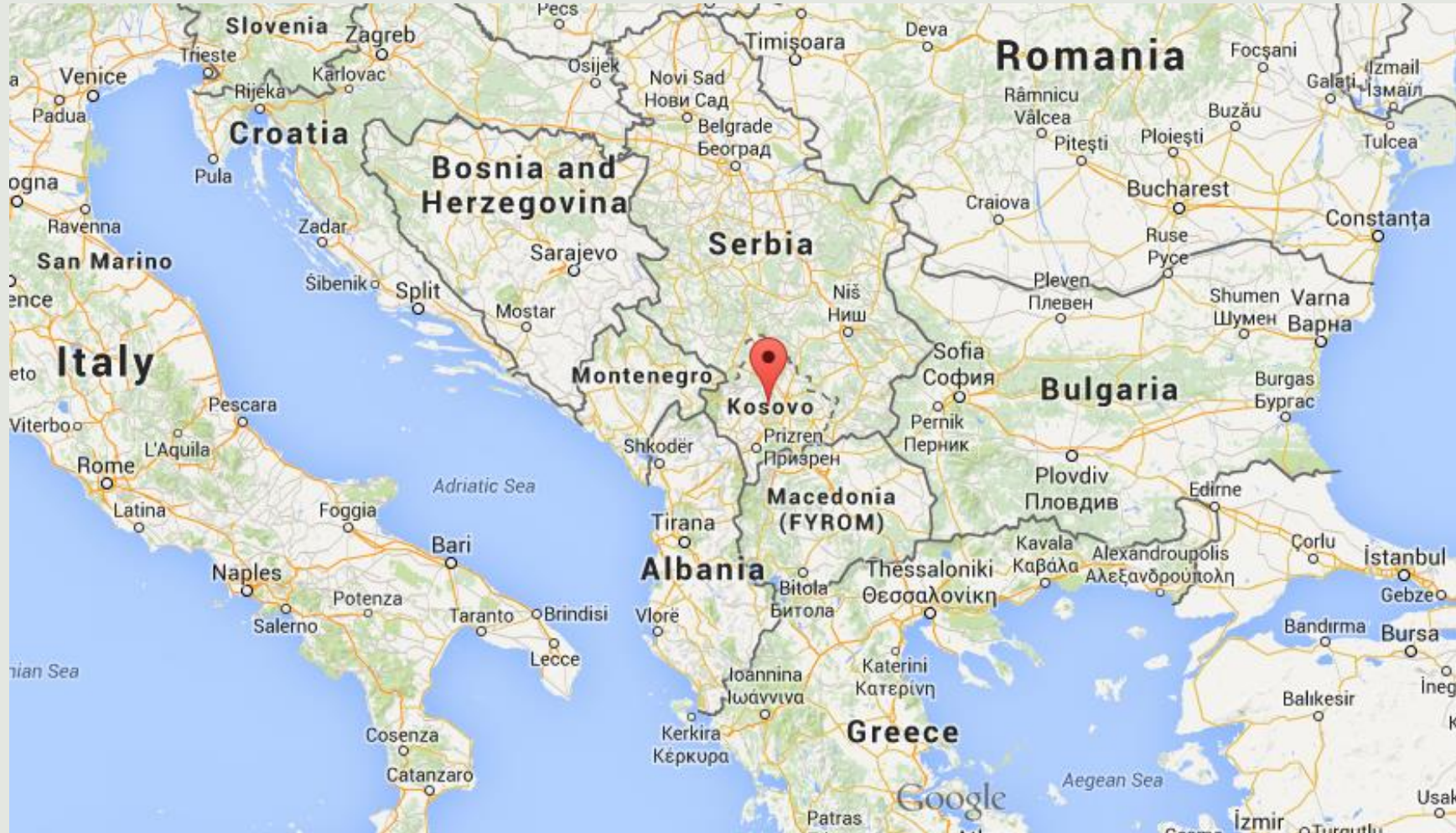
# Clean energy transition

To meet this challenge, we NEED:

- 1) Smart, responsive system
- 2) Infrastructure that enables renewable energy
- 3) Focus on technology and equity (environmental + health impacts)



# Why Kosovo?





# Case of Kosovo

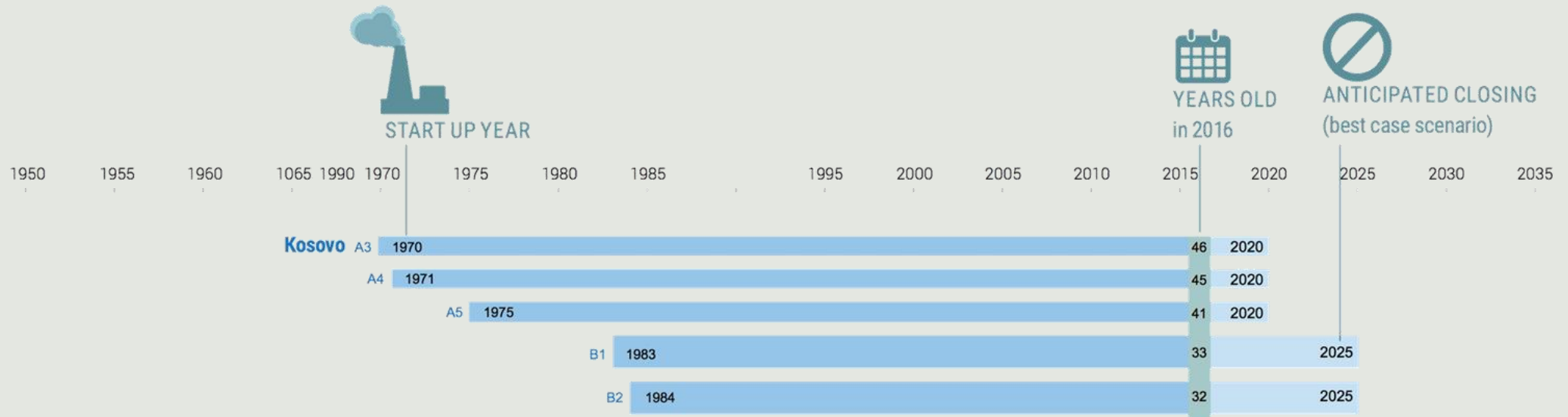






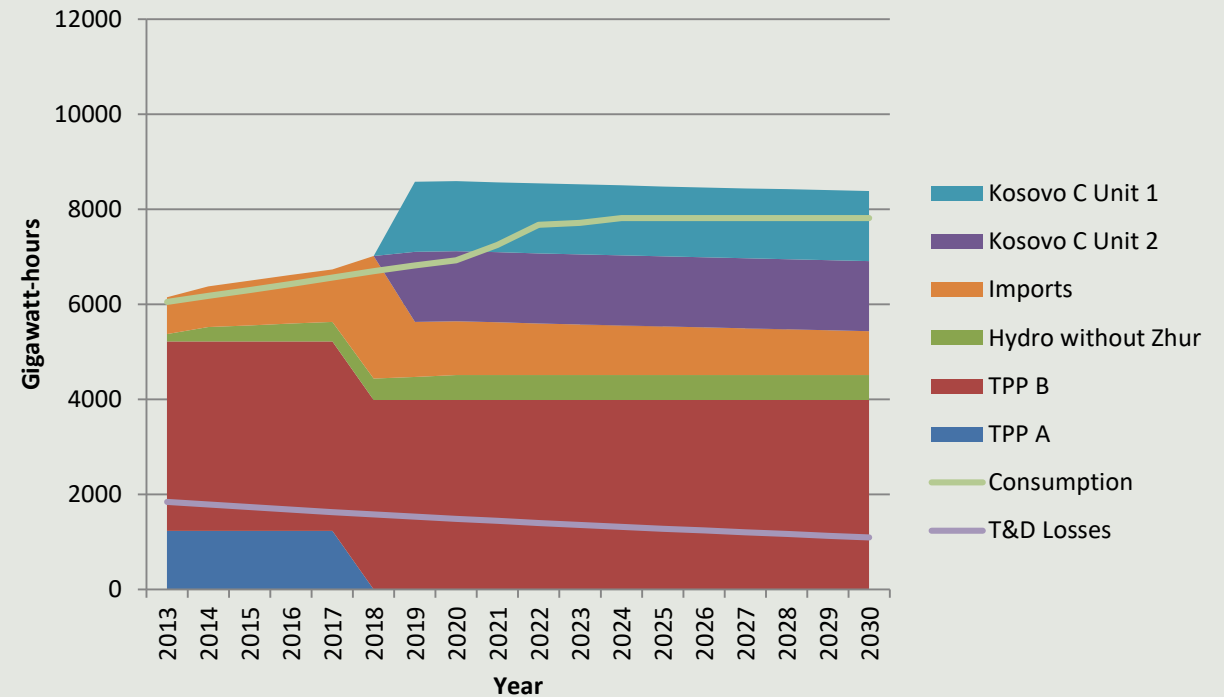


# Existing coal infrastructure in Kosovo



# Sustainable electricity options in Kosovo

**Motivation: World Bank plans loan for new infrastructure**

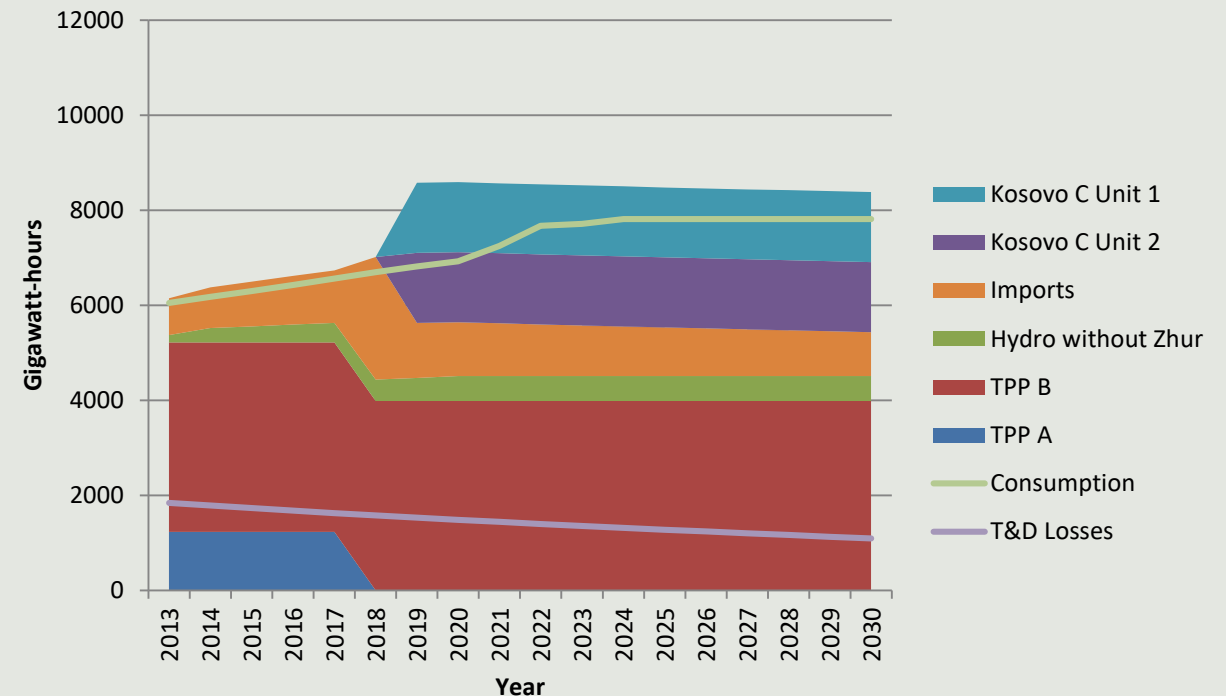


**FEATURED ARTICLE**

# Sustainable electricity options in Kosovo

Motivation: World Bank plans loan for new infrastructure

**Question: Are financially feasible alternatives to coal available in Kosovo to provide electricity at a lower cost?**



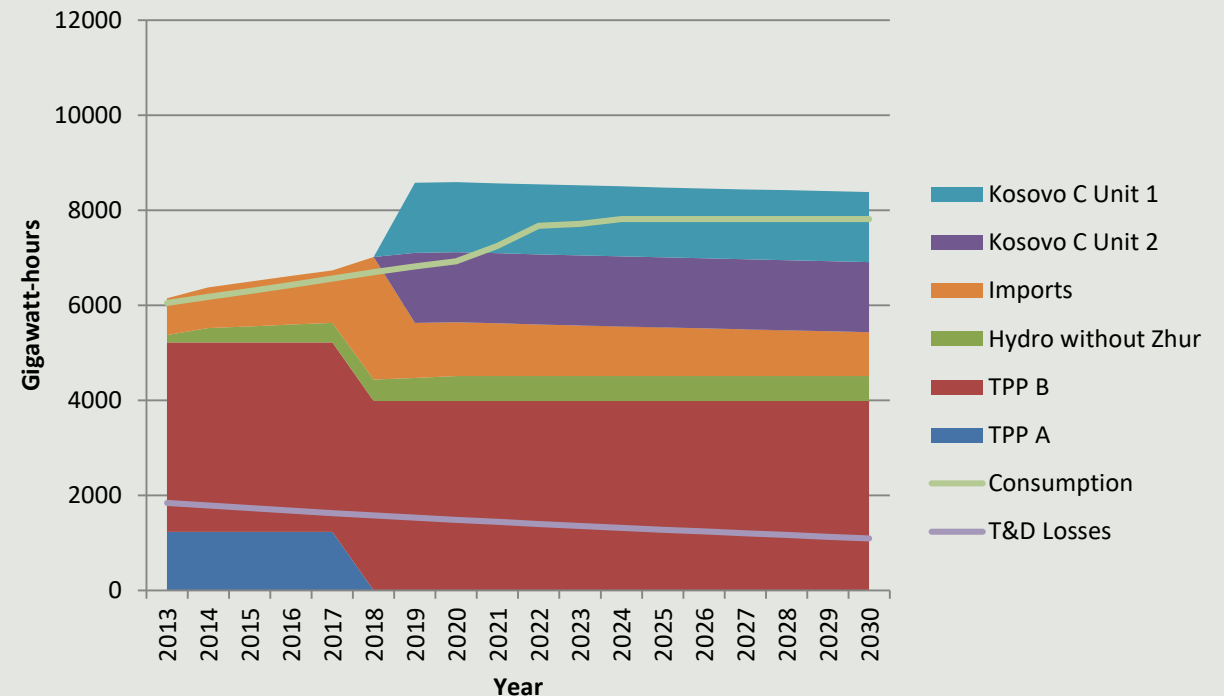
**FEATURED ARTICLE**

# Sustainable electricity options in Kosovo

Motivation: World Bank plans loan for new infrastructure

Question: Are financially feasible alternatives to coal available in Kosovo to provide electricity at a lower cost?

**Approach: Develop annual energy supply and demand model to compare cost of different options**



**FEATURED ARTICLE**

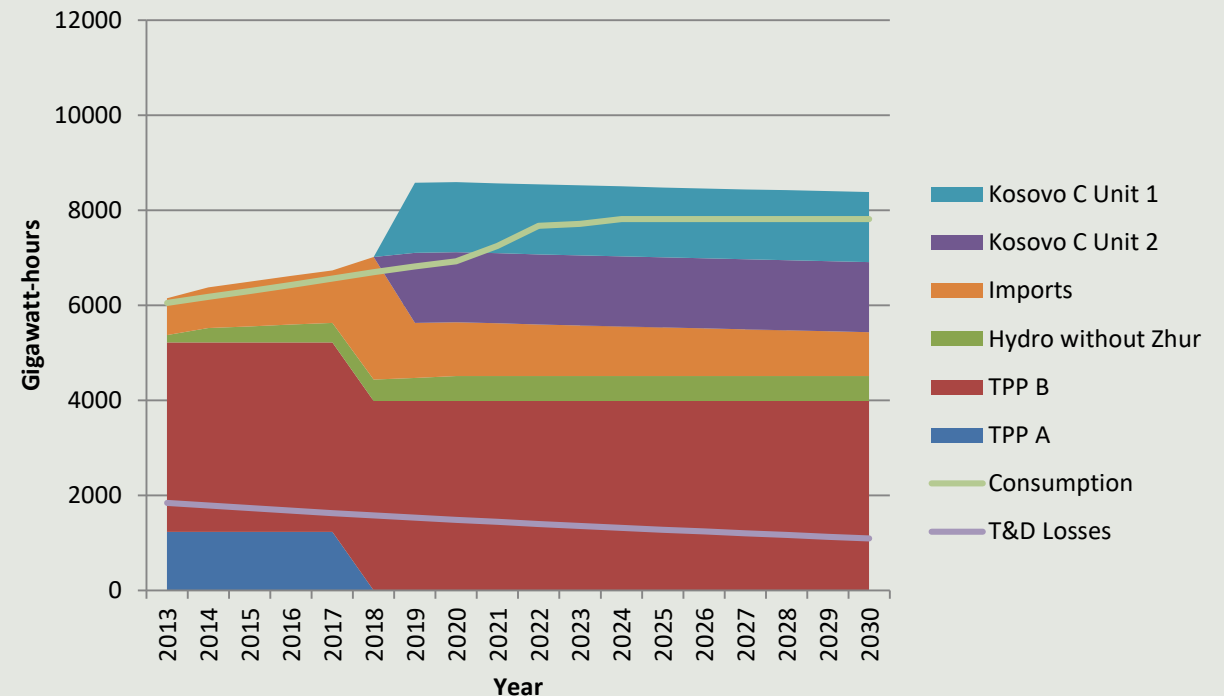
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Motivation: World Bank plans loan for new infrastructure

Question: Are financially feasible alternatives to coal available in Kosovo to provide electricity at a lower cost?

Approach: Develop annual energy supply and demand model to compare the cost of different options

**Result: Range of alternative technologies exist to meet annual generation of 600 MW coal plant at lower cost**



**FEATURED ARTICLE**

# Sustainable electricity options in Kosovo

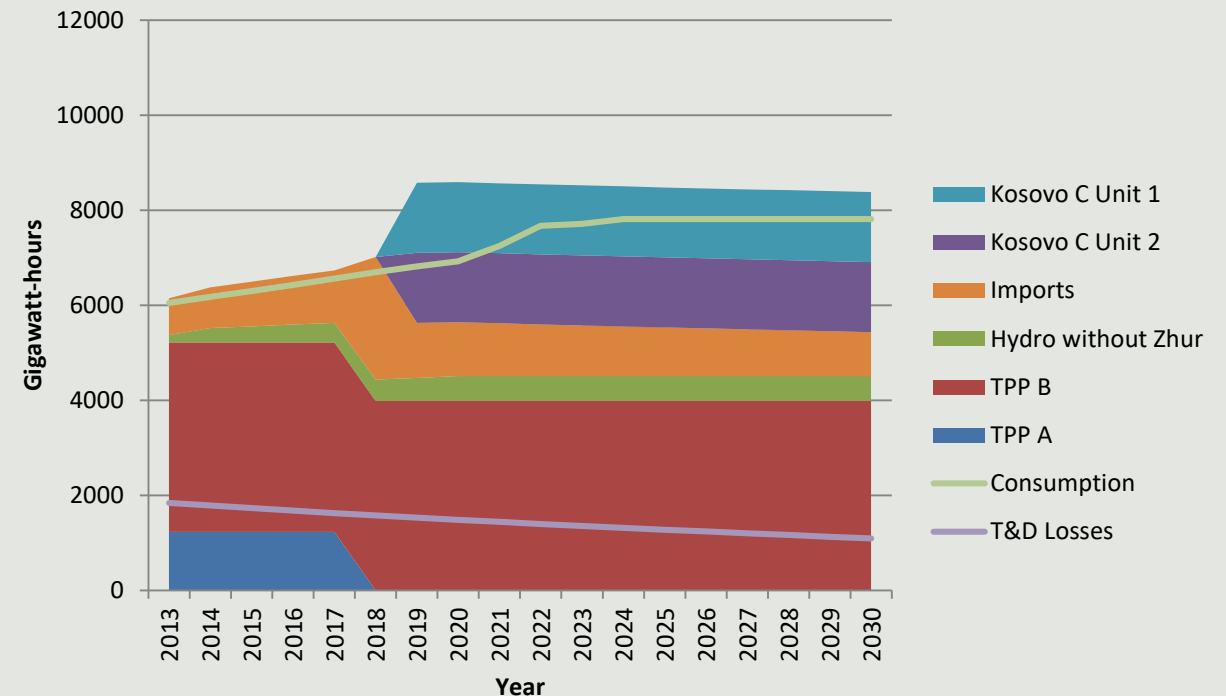
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Question: Are financially feasible alternatives to coal available in Kosovo to provide electricity at a lower cost?

Approach: Develop annual energy supply and demand model to compare the cost of different options

Result: Range of alternative technologies exist to meet annual generation of 600 MW coal plant at lower cost

**Significance: Challenges convention coal is least cost option when WB develops lending policy for new infrastructure**



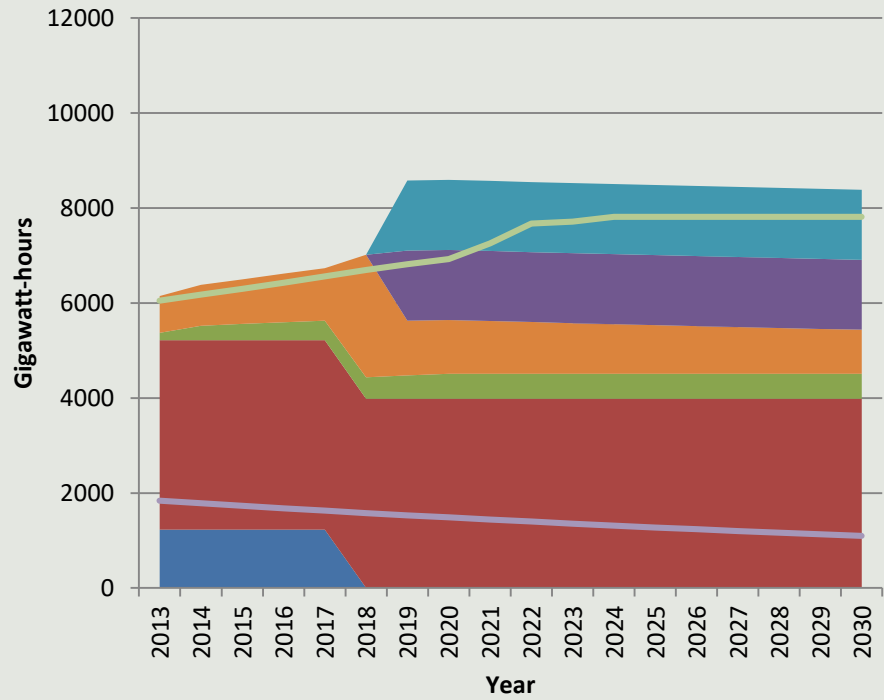
**FEATURED ARTICLE**

Scenario	Profile	Estimated Cost	Average LCOE
<h1>Base Case (coal)</h1>		<p><b>€1.96 billion EUR</b></p>	<p><b>€204/MWh</b> (€184/MWh- €224/MWh)</p>
<h1>Euro 2030 path</h1>		<p><b>€1.57 billion EUR</b></p>	<p><b>€160/MWh</b> (€150/MWh- €170/MWh)</p>
<h1>Expanded Regional Transmission Interconnections</h1>		<p><b>€1.76 billion EUR</b></p>	<p><b>€167/MWh</b> (€162/MWh- €172/MWh)</p>
<h1>Introduction of natural gas</h1>		<p><b>€1.55 billion EUR</b></p>	<p><b>€155/MWh</b> (€141/MWh- €169/MWh)</p>

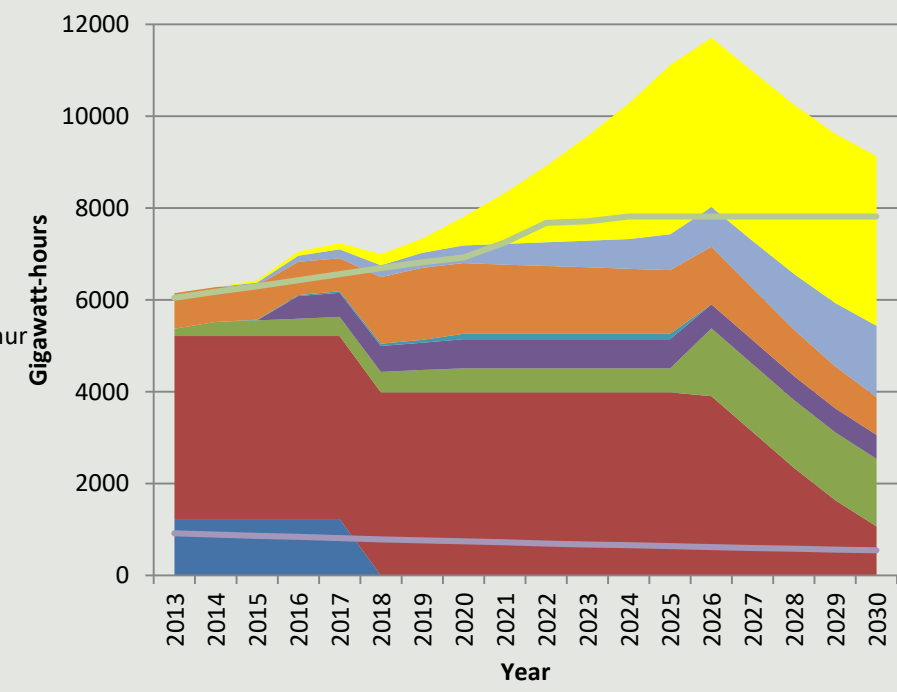
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# Base Case and Euro 2030

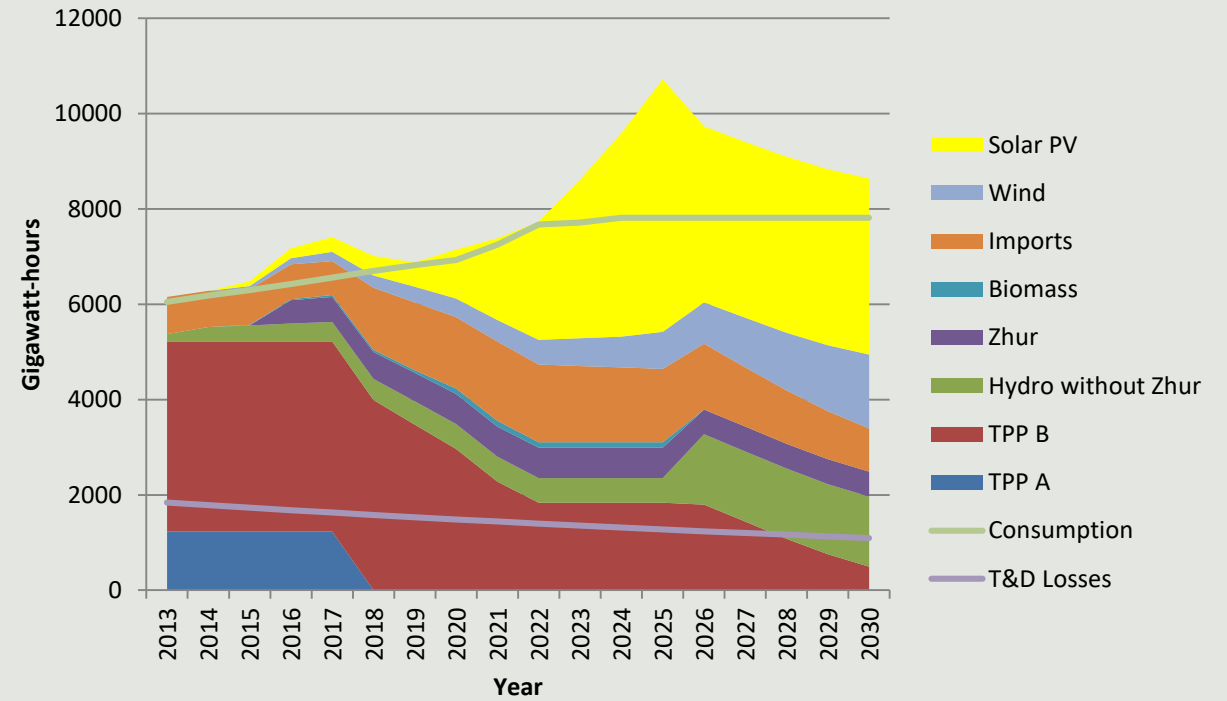
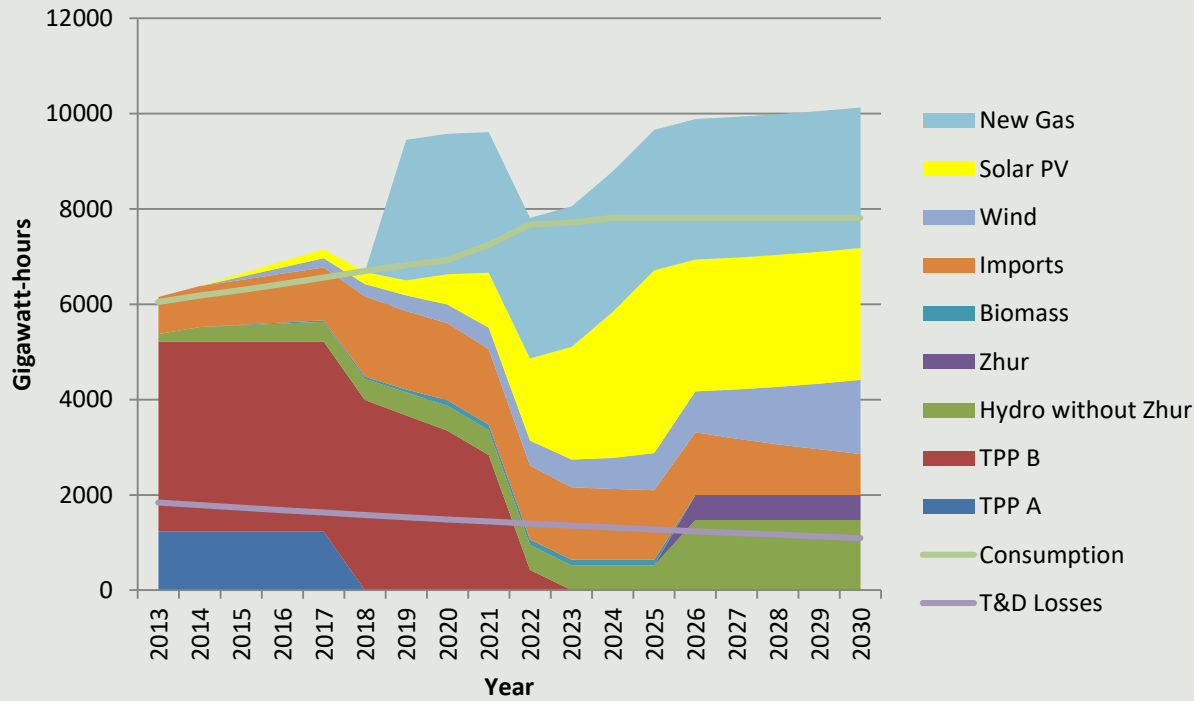


- Kosovo C Unit 1
- Kosovo C Unit 2
- Imports
- Hydro without Zhur
- TPP B
- TPP A
- Consumption
- T&D Losses

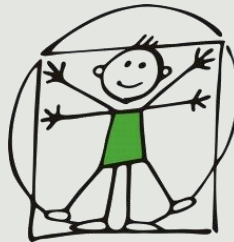
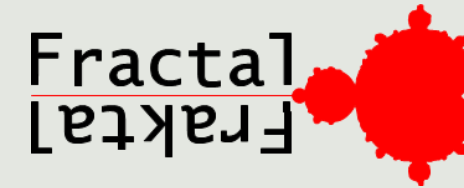


- Solar PV
- Wind
- Imports
- Biomass
- Zhur
- Hydro without Zhur
- TPP B
- TPP A
- Consumption
- T&D Losses

# Solar With and Without Gas



# Project Partners



# Particulate matter and public health

ENVIRONMENT

JANUARY 31, 2018 / 5:59 AM / A MONTH AGO

## Kosovo's pollution draws protesters as city bans cars from town center



Amb. Greg Delawie @USAmbKosovo · Jan 31

We know how he feels! Pollution is a serious issue in #Kosovo, I hope to see more government action to address it. Check out the #AirNowInPristina monitor to know when to stay inside: [goo.gl/639ZiV](http://goo.gl/639ZiV)



2 30 100



## Kosovo environmentalists protest heavy pollution levels



A Kosovo citizen wearing a gas mask participates in a protest against heavy pollution in Kosovo capital Pristina on Wednesday, Jan. 31, 2018. Hundreds of people staged a protest Wednesday in Kosovo's capital Pristina, urging the government to fight extremely high pollution. Protesters blamed the government and local authorities for allowing hazardous levels of fine particulate matter, an air pollutant called PM2.5. (Visar Kryeziu/Associated Press)



CHECK AIR QUALITY IN  
PRISTINA

MONITORED BY THE U.S. EMBASSY PRISTINA

# Systems-level modeling of energy infrastructure



DANIEL KAMMEN  
Professor and Director of the Renewable and Appropriate Energy  
Laboratory  
NOAH KITTNER  
University of California, Berkeley

## Energy in the Balkans

\* One critical way to expedite EU integration of the Balkans (“[Knocking on Heavens Door](#)”, August 29th) is to start by building an integrated energy system compliant with EU environmental standards and regulations. The proposed coal-fired power plant in Kosovo remains a prime example of a project that could set back EU accession by decades. Relying on lignite coal for electricity production in the region is not sustainable for the environment or public health. Linking electricity markets to take advantage of load balancing through hydropower projects in Albania and by creating a regional low-carbon roadmap will require significant cooperation—leadership traits that go hand-in-hand with joining the EU.



Article  
Cite This: *Environ. Sci. Technol.* 2018, 52, 2359–2367  
pubs.acs.org/est

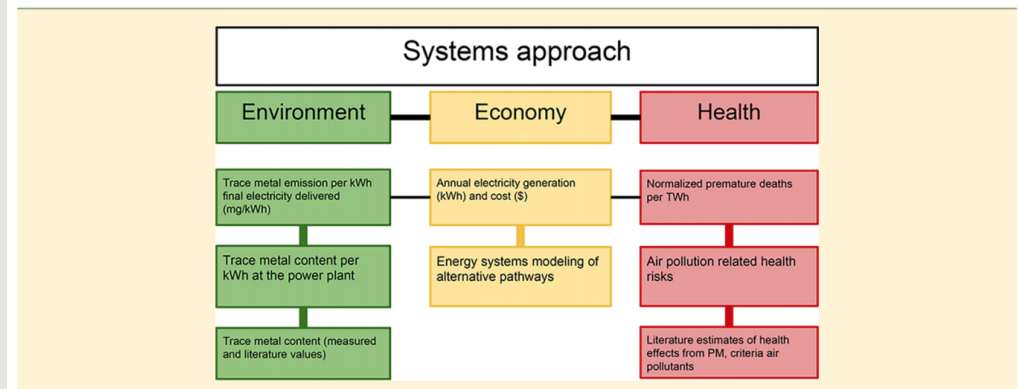
## Trace Metal Content of Coal Exacerbates Air-Pollution-Related Health Risks: The Case of Lignite Coal in Kosovo

Noah Kittner,<sup>†,‡,§,¶</sup> Raj P. Fadadu,<sup>§</sup> Heather L. Buckley,<sup>§,¶,Ⓢ</sup> Megan R. Schwarzman,<sup>§,||</sup> and Daniel M. Kammen<sup>\*,†,‡,Ⓢ,Ⓣ</sup>

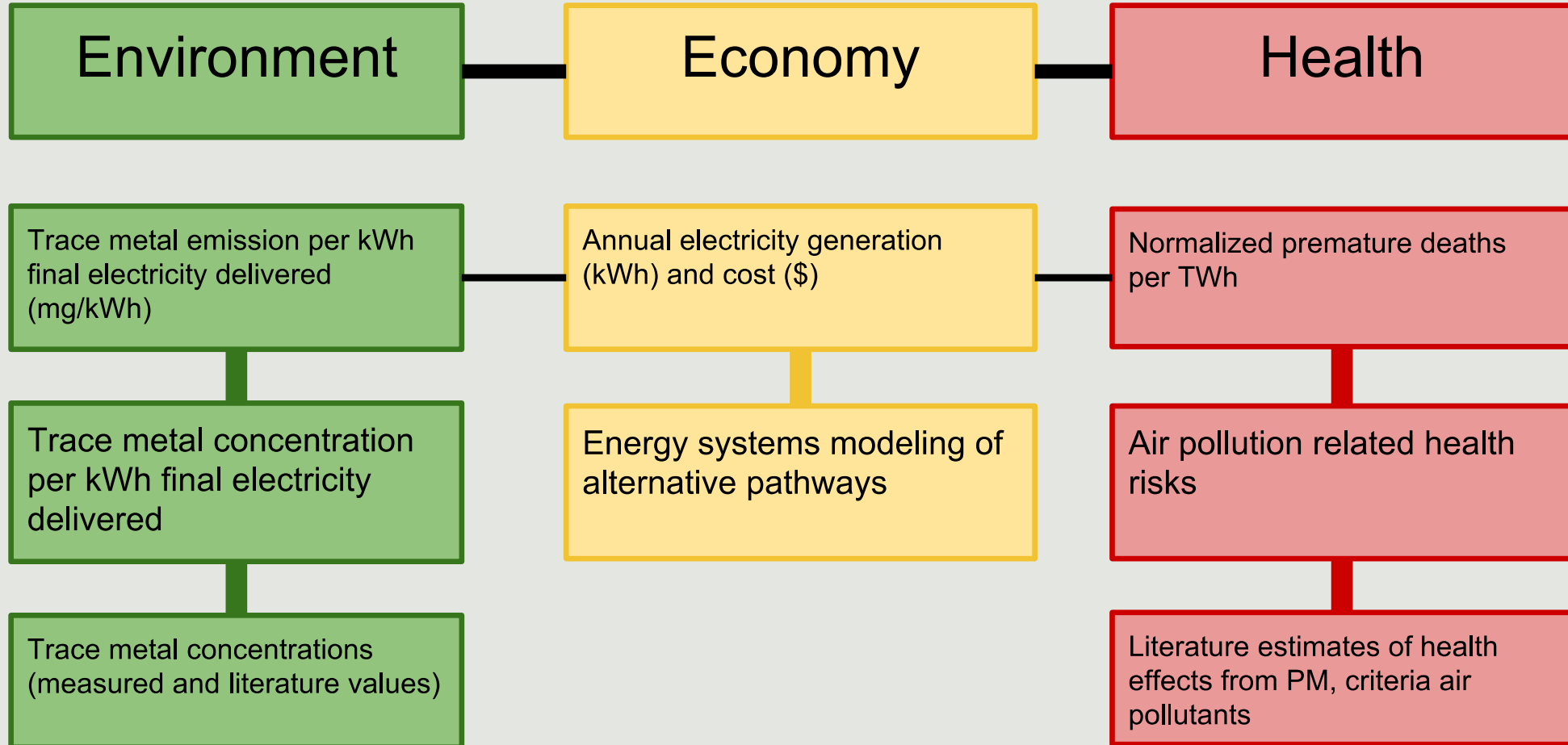
<sup>†</sup>Energy and Resources Group, <sup>‡</sup>Renewable and Appropriate Energy Laboratory, <sup>§</sup>Berkeley Center for Green Chemistry, <sup>||</sup>Center for Occupational and Environmental Health, and <sup>Ⓣ</sup>Goldman School of Public Policy, UC Berkeley, Berkeley, California 94720, United States

<sup>¶</sup>Energy Technologies Area, Lawrence Berkeley National Lab, Berkeley, California 94720, United States

### Supporting Information



# Systems approach





# Trace metals content

Motivation: Kosovo A & B are Europe's largest point source of air pollution

Question: What are the health risks and environmental impacts of coal use in Kosovo?

Approach: Life-cycle metric and modeling tool

*Trace metal concentration per final kWh electricity delivered*

Inductively-coupled plasma mass spectrometry (ICP-MS)

$$\frac{[\text{TM}]}{\text{kWhe}} = \frac{[\text{TM}] * n_t * n_d * (\text{heat rate}) * C_g}{Q}$$



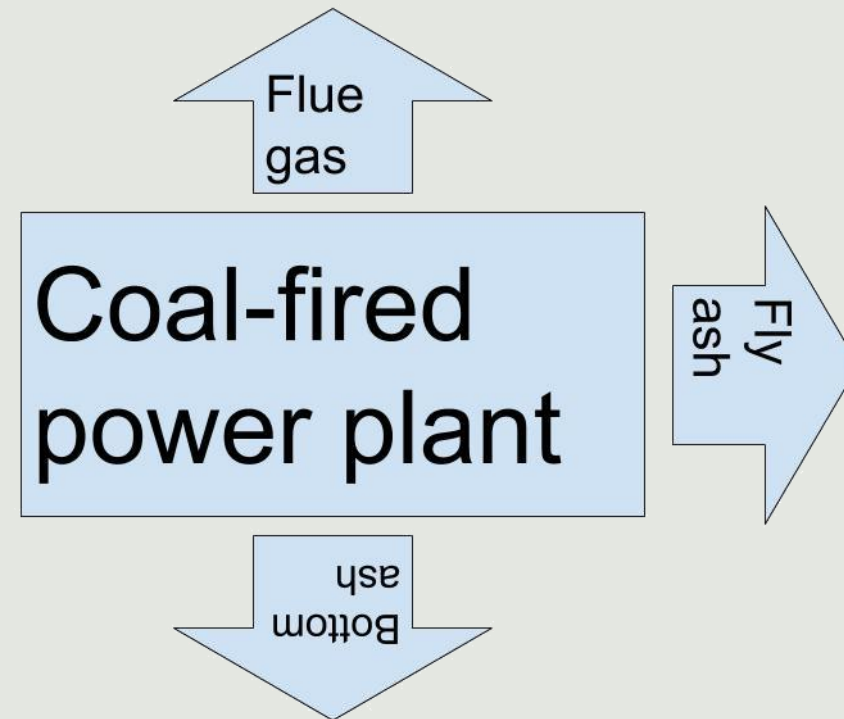
# Trace metal mass balance

$$M_c = C_c F_c = C_s F_s + C_a F_a + C_g F_g$$

Mass of coal

Concentration of coal

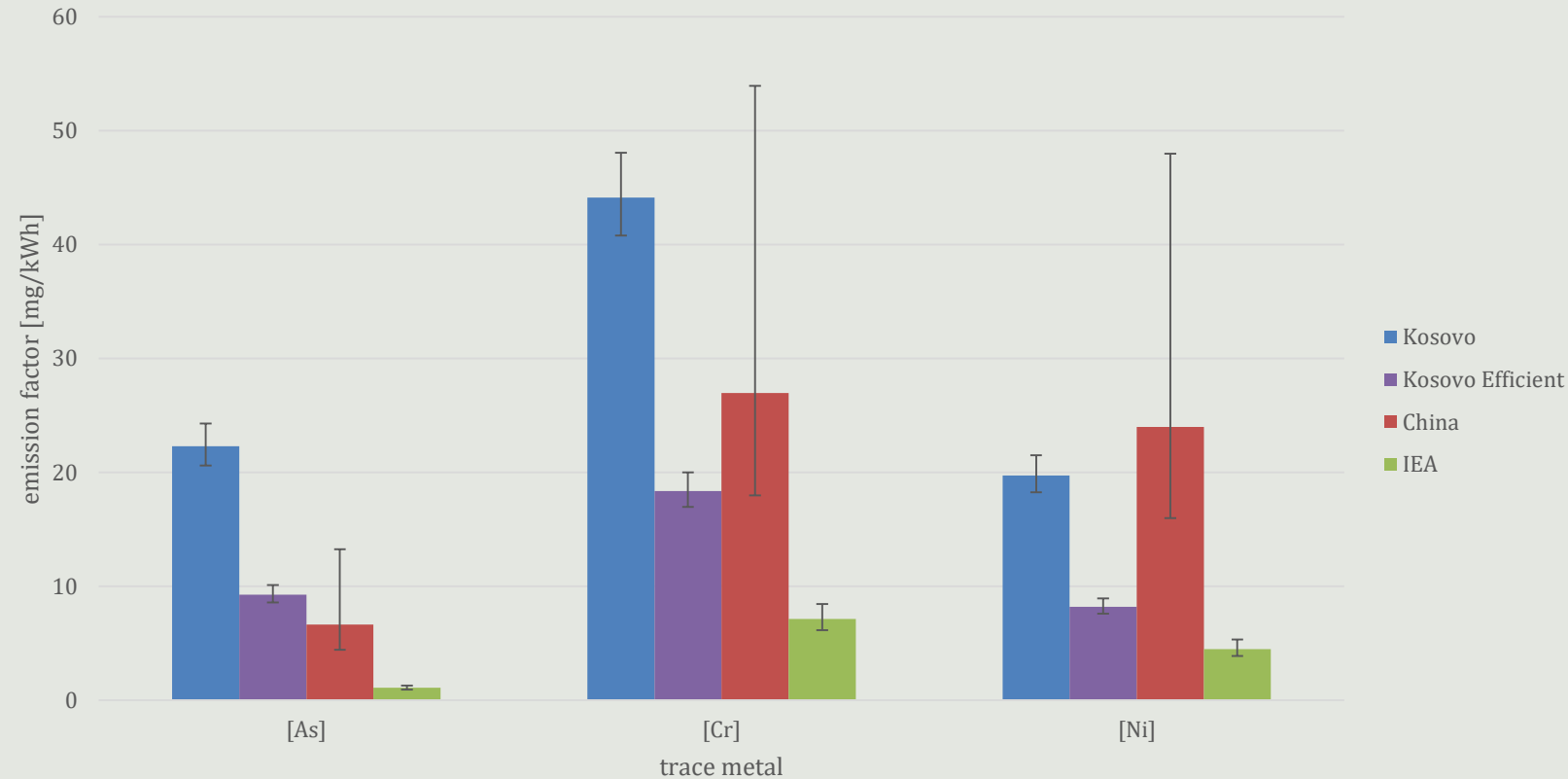
Flow rate







# ICP-MS for trace metal content in coal



Even with best available technology, coal poses health risks



# ICP-MS for trace metal content in coal

Natural gas may improve health risk?

Intermittency remains challenge

Development banks consider health risks?

	<u>Air pollution-related health risk</u>		
	Deaths	Serious illness	Minor illness
<b>Business-as-usual</b>	3,200 (800-12,700)	29,000 (7,300-88,000)	1,700,000 (430,000-6,900,000)
<b>Euro2030</b>	2,000 (510-8100)	18,500 (4,600-75,000)	1,100,000 (280,000-4,400,000)
<b>Solar without natural gas</b>	1,300 (320-5,200)	12,000 (2,900-47,000)	700,000 (180,000-2,800,000)
<b>Solar with natural gas</b>	900 (230-3,600)	8,400 (2,100-33,700)	460,000 (120,000-1,800,000)

# World Bank Annual Meetings



# ContourGlobal seeking equity partner for new Kosovo coal plant

